Engineering Design

K-12 Saturday STEM Workshop
Presented by
i-STEM and WYSTEM

Presented Saturday, May 9
by
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Make STEM Happen!
What is Engineering?
What is Engineering?

A typical definition from a first-year engineering textbook runs as follows:

“Engineering is the development of cost effective solutions to practical problems, through the application of scientific knowledge”

“engineering” in a very broad sense means any engagement in a systematic *practice* of *design* to achieve solutions to particular human problems.¹

What is ‘engineering’

By defining “engineering” more broadly, the emphasis is placed on engineering design practices beneficial for all students.
So....

What is Engineering Design?
Engineering Design is NOT just applied science.

Engineering design IS analogous to scientific practice, although engineering design has a different purpose and product than scientific inquiry.
Students are expected to:

• define problems—situations that people wish to change—by specifying criteria and constraints for acceptable solutions

• generate and evaluate multiple solutions

• build and test prototypes

• optimizing a solution
Defining and delimiting engineering problems involves stating the problem to be solved as clearly as possible in terms of criteria for success, and constraints or limits.

Designing solutions to engineering problems begins with generating a number of different possible solutions, then evaluating potential solutions to see which ones best meet the criteria and constraints of the problem.

Optimizing the design solution involves a process in which solutions are systematically tested and refined and the final design is improved by trading off less important features for those that are more important.
Emphasizing “test to failure” mentality
Engineering Design Challenge.....

Not just your ol’ toothpick and marshmallows...
Shake, Rattle and Roll

Design Challenge

Adapted from PBS's NOVAActivity The Day the Earth Shook
http://www.pbs.org/wgbh/nova/education/activities/2302_shook.html
Shake, Rattle and Roll

We study the effects of earthquakes on structures, such as buildings, bridges, and roads, and based on this, we want to design features that enhance a structure’s ability to withstand the effects of earthquakes. With your team, try building and testing structures to determine which features minimize the effects on a building when the earth shakes.

Design Challenge

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Shake, Rattle and Roll

Define the Problem

- Do Background Research
- Specify Requirements
- Brainstorm, Evaluate, and Choose Solution
- Develop and Prototype Solution
- Test Solution
- Based on results and data, make design changes, prototype, test again, and review new data.
- Solution Meets Requirements
- Solution Meets Requirements Partially or Not at All
- Communicate Results

Adapted from PBS's NOVA Activity "The Day the Earth Shook"
http://www.pbs.org/wgbh/nova/education/activities/2302_shook.html
Why we care.....

....the classic Tacoma Narrows example
Shake, Rattle and Roll

Strength of Geometric Shapes

Do Background Research
Shake, Rattle and Roll

Build structures able to hold a book 1.5”-2” off the ground. Explore which shapes are the strongest.

Construct a building of at least 30 cm (approximately 12 inches) tall that passes the test for your team’s challenge. You will need to use all the materials you are given. When your team has finished, test your structure by following the test procedure listed under your team’s challenge.
Challenge #1: High Impact
Design a structure that will remain standing even when a heavy book is dropped onto the floor next to the structure. Test:
Tape a piece of graph paper to the floor and place the building on the paper. You may not fasten the building to the floor or to the paper. Trace the foundation of the building with a pencil. Use a tape measure to find a height of 2m (approximately 2 yards) above the floor. Drop a heavy book onto the floor directly next to the structure. Carefully pick up the book and use a colored pencil to retrace the foundation of the building. Measure the distance that the foundation moved from its original spot on the paper.

Challenge #2: Hillside Home Design a structure on a slanted surface so the structure does not slide downhill even when an impact strikes the hillside. Build the structure on graph paper. Measure one end of the surface 8 cm (approximately 3 inches), so that this end is higher than the other end. Do not fasten the structure to the graph paper. Test: Use a pencil to trace the foundation on the graph paper and tape the paper to the hillside. Then drop a small weight, such as a packaged box of staples or a wrapped package of index cards, from a height of 30 cm (approximately 12 inches), directly above the uphill wall of the structure. Remove the weight carefully and use a colored pencil to retrace the foundation of the building. Measure the distance that the foundation moved when the weight was dropped.

Challenge #3: Rolling Along Build a structure on an unstable surface that will not fall down even when the surface moves beneath the building. Test: Fill most of the top of a shoe box with a single layer of marbles so that marbles can still roll. Set the building onto the marbles. Using a stopwatch or a clock with a second hand, begin sliding the box back and forth a distance of 5cm (approximately 2 inches) in each direction at a rate of 1 shake every 5 seconds. Increase the speed slowly until you are shaking once per second. The building may move, but it may not fall over. If it falls over, record the speed at which you were shaking when it toppled.
Shake, Rattle and Roll

Break into teams and make a plan

Brainstorm, Evaluate, and Choose Solution

Adapted from PBS’s NOVA Activity The Day the Earth Shook
http://www.pbs.org/wgbh/nova/education/activities/2302_shook.html
Shake, Rattle and Roll

Build your solutions

Adapted from PBS’s NOVA Activity The Day the Earth Shook
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Shake, Rattle and Roll

Test your solutions

Adapted from PBS's NOVAActivity The Day the Earth Shook
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Shake, Rattle and Roll

Did your solution work the way you expected?

Define the Problem

Do Background Research

Specify Requirements

Brainstorm, Evaluate, and Choose Solution

Develop and Prototype Solution

Test Solution

Solution Meets Requirements

Solution Meets Requirements Partially or Not at All

Communicate Results

Adapted from PBS’s NOVA activity “The Day the Earth Shook”

http://www.pbs.org/wgbh/nova/education/activities/2302_shook.html
Shake, Rattle and Roll

Revise and test again (theoretically)

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Communicate Results

Communicate results

Define the Problem

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Children are natural engineers. They spontaneously build sand castles, dollhouses, and hamster enclosures, and they use a variety of tools and materials for their own playful purposes. Children’s capabilities to design structures can then be enhanced by having them pay attention to points of failure and asking them to create and test redesigns of the bridge so that it is stronger.¹

“Scientists investigate that which already is; engineers create that which has never been.”

- Albert Einstein
“Scientists investigate what is; they discover new knowledge by peering into the unknown... Engineers create what has not been; they make things that have never existed before...”

~Joseph Bordogna, Deputy Director, National Science Foundation~ Albert Einstein
HI! I'M RAFAEL MANZANAREZ. I'M THE BRIDGE DESIGN MANAGER FOR THE NEW BAY BRIDGE.

IN 1989, AN EARTHQUAKE DAMAGED THE OAKLAND - SAN FRANCISCO BAY BRIDGE!

WE EXAMINED THE BRIDGE AND DECIDED TO BUILD A NEW BRIDGE - ONE THAT COULD WITHSTAND EARTHQUAKES EVEN STRONGER THAN THAT ONE!
What does it look like?

Engineering Design in K-2

Define
Identify situations that people want to change as problems that can be solved through engineering

Optimize
Compare solutions, test them, and evaluate each

Develop solutions
Convey possible solutions through visual or physical representations

What does it look like?
Engineering Design in 3-5

Define
Specify criteria and constraints that a possible solution to a simple problem must meet

Optimize
Improve a solution based on results of simple tests, including failure points

Develop solutions
Research and explore multiple possible solutions
What does it look like?

Engineering Design in 6-8

Define
Attend to precision of criteria and constraints and considerations likely to limit possible solutions

Optimize
Use systematic processes to iteratively test and refine a solution

Develop solutions
Combine parts of different solutions to create new solutions
What does it look like?
Engineering Design in 9-12

Define
- Attend to a broad range of considerations in criteria and constraints for problems of social and global significance

Optimize
- Prioritize criteria, consider trade-offs, and assess social and environmental impacts as a complex solution is tested and refined

Develop solutions
- Break a major problem into smaller problems that can be solved separately