EDUCATIONAL
ACTIVITY GUIDE

FROM THE GROUND UP: BLACK ARCHITECTS AND DESIGNERS

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CLASSROOM LESSONS

EDUCATIONAL PROGRAMMING SUMMARY

In this section, you will find five lesson plans that put students into the shoes of architects, engineers, and designers. These lessons are designed for formal classroom environments but can easily be adapted to more informal environments and, while designed for children ages 8-12, can be enjoyed by audiences of all ages. The lesson plans include specific Next Generation Science Standard connections, ideas for differentiated instruction as well as all the information you need to run the lesson. Consider these lesson plans a starting point for you to create your own customized classroom experiences.

Classroom Lessons Plans

Architectural Design

In this lesson, students will explore architectural design and act as architects to create a floor plan of a redesigned classroom. As designed this lesson is expected to run over two 60-minute periods.

Straw Bridges

In this lesson, students work in engineering teams to design, build and test model bridges as they determine how shapes affect the strength of structures. As designed, this lesson is expected to run approximately 60 minutes.

Dynamic Skyscrapers

In this lesson, students design, build, and test model skyscrapers as they learn about forces that affect real skyscrapers. As designed, this lesson is expected to run approximately 60 minutes.

Forces

In this lesson, students take on the role of engineers as they explore the variety of different forces that act upon structures. As designed, this lesson is expected to run over two 30-minute periods.

Newspaper Tents

In this lesson, students become engineers as they build a tent from newspapers and learn what shapes make structures strong. As designed, this lesson is expected to run approximately 60 minutes.

ARCHITECTURAL DESIGN

AT A GLANCE

Explore architectural design and act as architects to create a floor plan of a redesigned classroom.

OBJECTIVES

Students will:

- Use prior knowledge to discuss functions of various architectural structures
- Understand the difference between the job of an architect and the job of an engineer
- Explain what a floor plan is and how architects use them
- Be able to draw a floor plan to scale
- Create a floor plan of their classroom

RUN TIME

Two 60 minute periods

KEY VOCABULARY

Architect, Engineer, Floor Plan, Scale Drawing, Dimension Line

Next Generation Science Standards

Science and Engineering Practices:

- Asking Questions and Defining Problems
- Developing and Using Models
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
- Using Mathematics and Computational Thinking
- Constructing Explanations and Designing Solutions
- Obtaining, Evaluating and Communicating Information

Crosscutting Concepts:

- Patterns
- Cause and Effect
- Scale, Proportion, and Quantity

Disciplinary Core Ideas:

- ETS1: Engineering Design
- ETS 2: Links Among Engineering, Technology, Science and Society

ADVANCE PREPARATION

- Copy the “Architectural Design Student Information Sheet” for each student as well as several graph sheet pages.
- Make sure there are enough materials for each pair of students to have a ruler, meter stick, tape measurer, plain paper and graph paper.

MATERIALS

Per Pair:

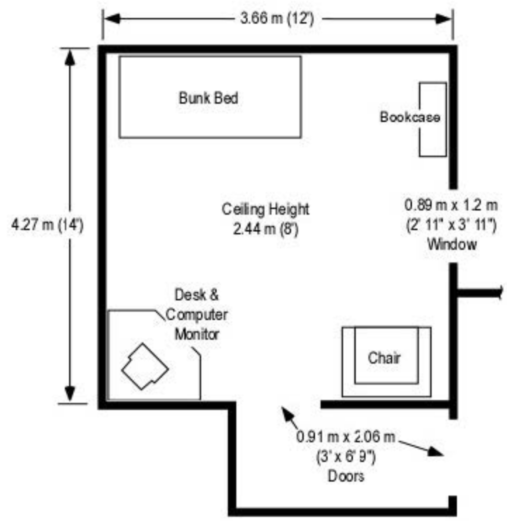
- At least 5 pictures of different buildings
- Pencil
- Ruler
- Meter stick
- Tape Measure
- 3-4 sheets of graph paper
- 3-4 sheets of plain paper

ARCHITECTURAL DESIGN

What You Need to Know

The job of architects and engineers involves planning and designing structures and then overseeing their construction. Architects create drawings and designs that are used to give engineers the information they need to build structures. Drawing plans with pens, pencils, or computers is called drafting. Architects decide on the size and shape of the structures they are designing and what materials should be used in the building of the structure. These designs need to be accurate so the engineers know exactly what to build. Such designs must take everything into account, including the purpose of the structure, the setting, materials being used and energy sources. Plans for structures must be very detailed using exact measurements. Architects draw and construct floor plans and models both by hand and by using sophisticated computer programs.

A floor plan is a drawing that shows a room as seen from above. Everything looks flat when drawn in a floor plan. Architects use floor plans to design rooms or whole buildings. Floor plans usually show measurements (called dimension lines) for how long things are in real life. Dimension lines show the lengths of windows, walls, doorways, closets and distances between these objects. Floor plans must be drawn to scale which means reducing the size of a drawing so a whole room or building can fit on one piece of paper. Common scales used are 1inch=1 foot or ¼ inch =1 foot. Below is an illustration showing a simple floor plan of a bedroom drawn with dimension lines.



Helpful vocabulary words and definitions:

- Architect - a person who plans and designs how a building looks; the art of the building.
- Engineer – a person who plans the structure of a building including materials used and how the building will support its weight; the science of building.
- Floor Plan – a drawing that shows a room seen from above.
- Scale Drawing - a drawing that represents a real object reduced in size.
- Dimension Line – a line showing a measurement in a scale drawing.

Warm Up

1. Discuss with the students what makes up a city and have them share their ideas. Tell them that, in addition to people, businesses and trees, buildings are a major part of a city and they will be taking a closer look at the different types of buildings that make up a city.
2. Give each group of students at least five pictures of different types of buildings and ask them to categorize them. Tell them to take a few minutes to look over the pictures and make a list of the

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types of buildings represented. They may write down specific building names (i.e. the Willis Tower and the Art Institute) or they may think more generally (i.e. office building, museum).

3. After a few minutes of brainstorming, have each group share their list. Write down their ideas on a board or chart paper.
4. After each group has shared their ideas, work together to create a general list of the types of buildings found. For example, if they say the Willis Tower, have them categorize it as an office building or skyscraper. Also guide them to think of other types of buildings that may not be represented in the pictures: grocery stores, schools, train stations, etc.
5. Once they have created a fairly large list, ask them: Why do you think there are so many different types of buildings? Why is a house so different from a skyscraper? Encourage the students to think about the purpose of these different kinds of buildings. A house has a very different purpose than a skyscraper, and so they look different. A house also has different things inside it compared to a skyscraper. Ask the students to make comparisons between the two.
6. Typically, the inside and general look of a house and a skyscraper are very different. But, ask the students, are there any similarities in how they are constructed? Who designs these types of buildings?

Activity

1. Talk to the students about architects and engineers and how their jobs are related, but different. An architect's job is to come up with the design concept of a building, while an engineer's job is to do the actual building. Explain that it is very important for architectural drawings to be accurate, because the engineers and builders must be able to follow them exactly. Careful measurements must be used to be certain that the building will turn out the way the architect wants it to be built.
2. Show students the Student Information Sheets illustrating two different types of floor plans. Floor plans can be drawn with pictures of the actual objects or with line drawings.
3. Give students graph paper and decide on a scale for them to use. Graph paper lends itself to use the scale ¼"=1 foot. Each square of graph paper is ¼" long. Explain to students that something that is ¼" long in a floor plan is 1 foot long in real life. For example, if a classroom wall is 20 feet long, students can divide by 4 and draw a line 5" long, or they can count 20 boxes on the graph paper.
4. Have students practice measuring objects such as a textbook, pencil, or desk and then drawing them to scale on their graph paper.
5. Organize the class to work in pairs to draw a floor plan of their classroom. Ask each pair to create a sketch of their classroom on plain paper which includes the location of walls, windows, doorways, and closets.
6. After they are finished sketching, ask each pair to measure the length and width of the classroom and record it on their sketch.
7. Next, ask each pair to measure the length and width of any doorways, windows, or closets. Remind students they don't need to worry about height because in a floor plan, everything is flat.
8. Once students have the measurements of the classroom, they are ready to make their floor plans. Students should begin by drawing the classroom walls with thick lines. They can then add in windows, doorways, or closets by erasing the thick lines to make room for openings, or draw new thin lines.
9. After the students are finished drawing the classroom, they can add dimension lines and a key. Students can also draw in other objects in the classroom such as furniture if they would like.

The amount of detail included can be determined by the skill level of the class.

10. Discuss the drawings. What was difficult to represent? What was easy about the drawings?

Check for Understanding

Have students answer the following questions in their teams or as a whole group discussion.

- Why do you think there are so many different types of buildings?
- Why is a house so different from a skyscraper?

As student groups are working on their floor plans, walk around and ask them to explain what they are drawing. Ask them to show you where the doors, windows, closets, etc. are located and have them show you their dimension lines. Check to be sure they are making their floor plans to scale.

What's Happening

In architecture and building engineering, a floor plan is a drawing to scale, showing a view from above, of the relationships between rooms, spaces and other physical features at one level of a structure.

Dimensions are usually drawn between the walls to specify room sizes and wall lengths. Floor plans may also include details of fixtures like sinks, water heaters, furnaces, etc. Floor plans may include notes for construction to specify finishes, construction methods, or symbols for electrical items.

Differentiated Instruction

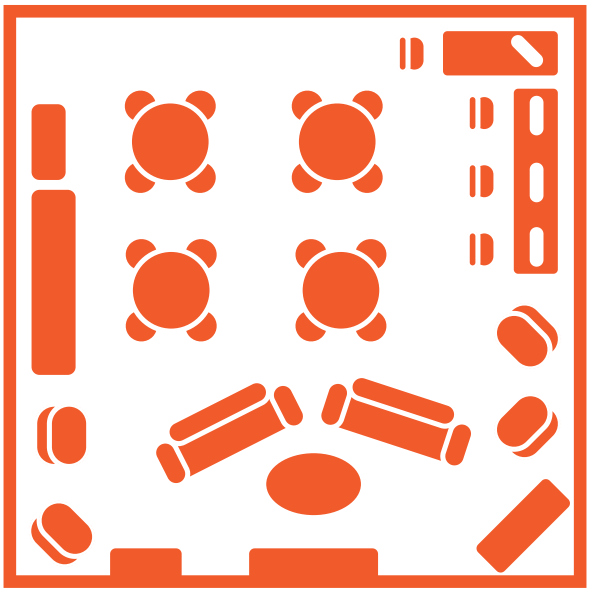
- More advanced students can design their "dream classroom." Ask students to think about what they would like their ideal classroom to look like and sketch it on plain paper. How big would the classroom be? What would they include in their classroom? After they have a sketch of their dream classroom, ask them to make a floor plan including measurements of the room.
- Ask students to make a sketch of their classroom and practice measuring the walls, windows, doorways, etc. Include the measurements in the sketch.

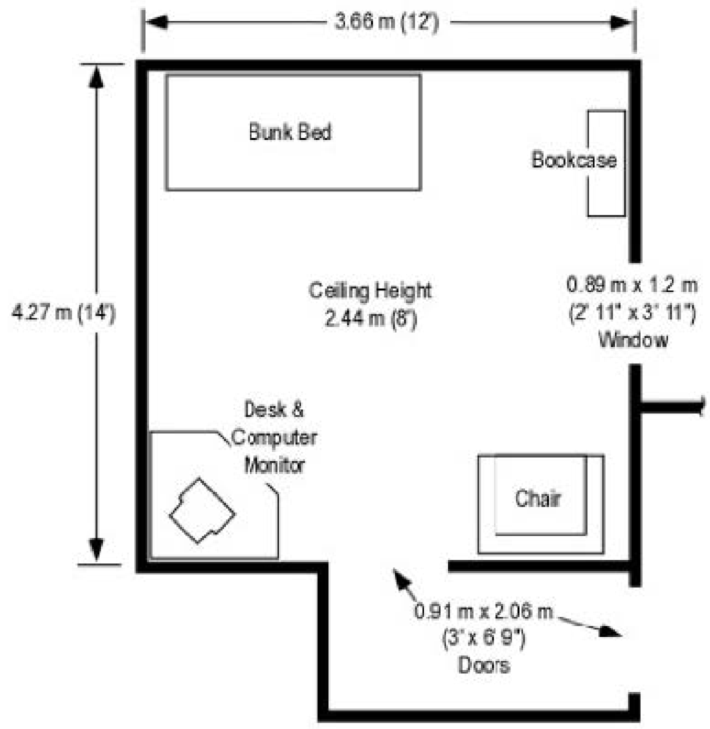
Extensions

- Ask students to write an essay describing a design for their perfect bedroom. If they could have a bedroom all to themselves and include anything they like, what would it look like? Students should include a drawing of the room.
- Have students do research on architects and engineers. What are the specific jobs of each of these careers? How are they similar? How are they different? Ask students to write a paper describing which career they feel they would be more suited for and why.
- Reading a floor plan is similar to reading a map. You need to understand measurements and scale. Have students search for architectural floor plans on the internet and examine them. In what scale did the architect design? What other details and measurements are important?
- Have students practice conversion skills by converting the floor plan measurements into the metric system.
- Have students draw a floor plan on cardstock, cut out all the furniture and movable objects, and rearrange them to make a new floor plan. How else could you arrange the room while including all the same features?
- The Incas built an incredible city called Machu Picchu. Show PBS NOVA's "Ghosts of Machu Picchu", Chapter 5: Remarkable Engineering. Discuss some of incredible feats of engineering, e.g. how to access fresh water that the Incas used to create this once thriving city. What types of tools did they use?

Architectural Design Student Worksheet

Floor plans can be drawn with pictures of the actual objects such as the following:





Architectural Design Student Worksheet

Use the graph paper below to draw a detailed floor plan of your classroom.

DYNAMIC SKYSCRAPERS

AT A GLANCE

Students design, build, and test model skyscrapers as they learn about forces that affect real skyscrapers.

OBJECTIVES

Students will:

- Learn that engineers must consider dynamic loads like wind, earthquakes, and other forces when designing skyscrapers
- Learn how different design elements play into the structural integrity of a building
- Use critical thinking skills to evaluate structural design

RUN TIME

60 minutes

KEY VOCABULARY

Skyscraper, Engineer, Dynamic Loads, Force, Structural Design, Blueprint

Next Generation Science Standards

Science and Engineering Practices:

- Asking Questions and Defining Problems
- Developing and Using Models
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
- Using Mathematics and Computational Thinking
- Constructing Explanations and Designing Solutions
- Obtaining, Evaluating and Communicating Information

Crosscutting Concepts:

- Patterns
- Cause and Effect
- Scale, Proportion, and Quantity
- Structure and Function

Disciplinary Core Ideas:

- ETS1: Engineering Design
- ETS 2: Links Among Engineering, Technology, Science and Society

ADVANCE PREPARATION

- Designate a table in front of the class where students can test their building's ability to withstand strong wind. Place two hair dryers or fans on the table.
- Designate a second table in front of the class where each group can test their building's ability to withstand an earthquake.
- Construct a skyscraper that is 61 cm tall or tape two or more paper clips together to use in the demonstration.

MATERIALS

Per Class:

- Pictures of skyscrapers
- Four or more meter sticks
- Two tables
- Two hair dryers or fans
- Building supplies such as:
  - — balsa wood
  - — wood glue straws
  - — popsicle sticks
  - — newspaper
  - — tape
  - — Q-Tips
  - — rubber cement
  - — paper clips
  - — toothpicks
  - — card stock
- pipe cleaners
- paper or plastic
- cups
- playing cards

DYNAMIC SKYSCRAPERS

What You Need to Know

When designing buildings, engineers must consider dynamic loads which are loads that can change quickly over time. Wind and earthquakes are two examples of dynamic loads.

As wind hits the side of a building, it puts pressure on the windward side of the building and creates suction on the opposite side. Therefore, if a building and its windows are not designed correctly, a strong gust of wind could push the building's windows in on one side and blow them out on the other. Buildings must be flexible enough to absorb this force, but if a building is too flexible, people on the top floors may get sick from feeling the building sway back and forth.

The effect of an earthquake on a building is similar to the effect of strong wind. However, wind usually blows in smooth gusts while earthquakes act in a quick jerk, making them more dangerous. This is because a sudden applied force is greater than a force applied slowly. With an earth quake, a sudden change in force can cause structures to collapse, so buildings in earthquake areas must be constructed differently in order to avoid collapsing.

Warm Up

1. Show students pictures of skyscrapers or tall buildings like the Willis (Sears) Tower or John Hancock Center. Ask students, "What do engineers need to think about when designing and constructing tall buildings? What challenges will their skyscrapers have to withstand?" (Answers will vary but should include forces such as wind, earthquakes, rain, snow; loads such as people, furniture.)
2. Discuss dynamic loads with students (refer to the What You Need to Know section).

Activity

1. Tell students they will be working in engineering teams to design and construct a 61 cm tall skyscraper that must be able to withstand two different dynamic loads: strong winds and earthquakes.
2. Demonstrate what students will do with their model skyscrapers at the two testing stations. At the "wind" table, place your skyscraper in the center of the table, point one hair dryer or fan at it and turn it on. If your skyscraper is strong enough to withstand the wind from one hair dryer, try two hair dryers. At the "earthquake" table, place your skyscraper in the center of the table. Students will stand around the table and gently shake the table to simulate an earthquake.
3. Divide students into groups of two to four.
4. Give students five minutes to brainstorm what their building will look like and to draw a blueprint.
5. Pass out building supplies.
6. Give students 30 minutes to build their 61 cm tall skyscraper.
7. After 30 minutes, allow groups to test their buildings one at a time in front of the whole class.

Check for Understanding

Have students answer the following questions in their teams or as a whole group.

- In your own words, how would you describe a dynamic load? What are two examples of dynamic loads?
- Did your skyscraper pass or fail the wind and earthquake tests? If it failed, what would you do differently? If it was successful, why?
- Would you want to become an engineer? Why or why not?

DYNAMIC SKYSCRAPERS

What's Happening

In the real world, wind speeds increase with height so wind blows faster at the top of a skyscraper than at the bottom. A heavier base will make for a sturdier, more balanced building. Buildings that have more weight at the bottom of the structure than the top will withstand both the wind and the earthquake tests better.

Differentiated Instruction

- Depending on the level of the students they can have varying building challenges.

Extensions

- Have students draw a picture of their skyscraper and write an advertisement persuading people to live or work in their building. When they are finished, have each group present their advertisement.
  - How much would rent be?
  - What amenities would their skyscraper have?
  - Where would it be located?
  - What would they name it?

STRAW BRIDGES

AT A GLANCE

Students work in engineering teams to design, build and test model bridges as they determine how shapes affect the strength of structures.

OBJECTIVES

Students will:

- Plan, design, build and test a model truss bridge.
- Identify effective geometric shapes used in bridge design.
- Identify several factors that engineers consider when designing bridges.

RUN TIME

60 minutes

KEY VOCABULARY

Beam, Beam Bridge, Bridge, Dead Load, Deck, Engineer, Live Load, Loads, Span, Truss

Next Generation Science Standards

Science and Engineering Practices:

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Analyzing and interpreting data
- Using mathematics and computational thinking

Constructing explanations and designing solutions

- Obtaining, evaluating and communicating information
- Crosscutting Concepts:
- Patterns
- Cause and effect
- Scale, proportion and quantity
- Structure and function

Disciplinary Core Ideas:

- ETS1: Engineering design
- ETS 2: Links among engineering, technology, science and society

ADVANCE PREPARATION

- (Optional) If doing the Warm Up as a demonstration rather than a whole group activity, construct straw model shapes as pictured in the Warm Up section.
- (Optional) Post the requirements for students' bridges.

MATERIALS

Per group:

- 20 plastic, non-bendy straws (29 if doing the Warm Up as a whole group activity)
- Roll of clear tape
- Scissors
- Meter stick (or one for the class to share)

Per class:

- Small paper cup
- 200 to 300 pennies (to use as weight)
- Two tables
- (Optional) Balance (for weighing; or, count the pennies instead of weighing)

STRAW BRIDGES

What You Need to Know

A bridge is a structure that spans a gorge, valley, road, railroad track, body of water, or any other physical obstacle for the purpose of providing passage over the obstacle.

There are many types of bridges: beam, truss, arch, suspension and cable-stayed. A truss bridge is a bridge that uses trusses, or a series of triangles, for support.

Truss bridge construction developed rapidly during the Industrial Revolution; they were first made of wood, then of iron and finally steel. During this time, different truss patterns also made great advances. The Howe Truss, one of the more popular designs, was patented by William Howe in 1840. His innovation was using vertical supports in addition to diagonal supports. The combination of diagonal and vertical members created impressive strength over long spans; this made the truss design ideal for railroad bridges.

Engineers must consider loads when building structures. Loads are weights and forces that a structure must withstand. The dead load of a structure is the weight of the structure itself. The dead load of a bridge, for example, includes beams, cables and the deck. The live load of a structure is the weight that is added to the structure, including people, cars and wind.

Helpful vocabulary words and definitions:

- Beam - A long, rigid, horizontal support member of a structure.
- Beam bridge - A bridge that consists of beams supported by columns (piers, towers).
- Deck - The "top" of the bridge on which we drive or walk.
- Engineer - A person who applies her/his understanding of science and mathematics to create things for the benefit of humanity and our world.
- Span - The distance a bridge extends between supports.
- Truss - A structural frame based on the geometric rigidity of the triangle and composed of straight members.
- Deflection - The distance a bridge bends down when a load is placed on it. In real bridges, deflection is normal as long as the bridge returns to its original position when the load is removed.

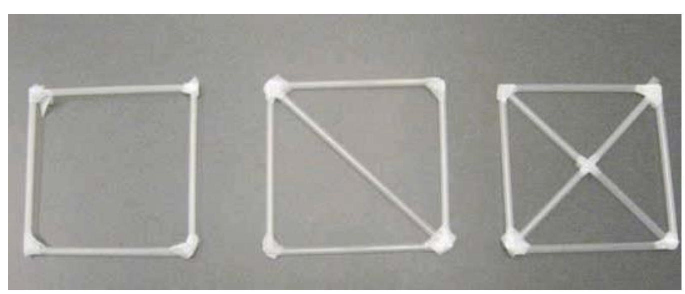
Warm Up

This may be done as a demonstration or a whole group activity. Ask students, "Which shape is more stable, a triangle or a square?"

As a demonstration

1. Show students that squares are less stable than triangles by showing the example straw shapes made in advance as pictured.
2. Stand the shapes up on a desk and push down on the top of them. With very little force applied, the open square shape twists while the square shape composed of inner triangles withstands much more force.
3. Discuss with students that this is the reason triangles are used in structures such as bridges.

As a group activity



4. Divide students into teams of two. Give each group nine straws, scissors and tape.
5. Tell the students to construct two squares. In one

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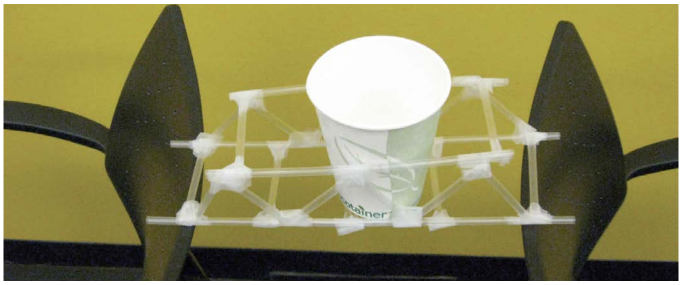
STRAW BRIDGES

of the squares place a diagonal piece, creating two inner triangles (like the middle square pictured above).

6. Have the students stand the shapes up on a desk and push down on the top of them. With very little force applied, the open square shape twists while the square with the inner triangles withstands much more force.
7. Discuss with students that this is the reason triangles are used in structures such as bridges.

Activity

1. Tell the students that for this activity they are engineers who have been hired to create a bridge that crosses a local river. Your bridge must meet these requirements:
   - The bridge must span 25 cm across two tables or chairs. It cannot be attached to the support structures in any way, so you may want to make your bridge slightly longer than 25 cm.
   - You will have limited supplies of clear tape and 20 straws. You can cut your straws to any length, but you will not be given any additional straws.
   - The bridge must support as much weight as possible. To simulate the load, your bridge must securely hold a small cup. You will then place pennies into the cup and count how many your bridge can hold.
   - Your bridge cannot disturb the river's fish population below, so your bridge cannot bend down more than 9 cm as pennies are being placed on it. This will be measured by placing a meter stick next to your bridge vertically as you place pennies on it.
2. Have students think critically bout the design of their bridge and start sketching a blueprint. Make sure they have enough time to brainstorm ideas, draw sketches, and make plans and calculations.
3. Give each team 20 straws, clear tape, and scissors. They are not allowed any extra supplies.
4. Have students build their bridge (allow about 20 to 30 minutes).
5. When they are finished, have each group predict how many pennies they think their bridge can hold. Record their predictions on the board.
6. Begin testing the bridges by placing a bridge on two tables or chairs that are 25 cm apart.
7. Position a small paper cup on the center of the bridge. Place a meter stick next to the bridge vertically, and use it to measure the bridge's height.
8. Gradually fill the cup with pennies until the bridge either collapses or bends down 9 cm (where the "water" would be).
9. Record the number of pennies each bridge was able to hold next to their hypothesis.



10. (Optional) Have students weigh the cup and the pennies on the balance and record the actual load next to their hypothesis.

Tip

Post the following criteria for students so that they can refer to it as they are designing and constructing their model bridge.

Bridges must meet the following criteria:

- It must span at least 25 cm.
- It must have a place in the center of the span that

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can securely hold a small paper cup.

- No part of the bridge may touch the "water" by dipping down 9 cm.
- The bridge cannot be taped to the support structure.
- Materials are limited. You can cut your straws to any length, but you will not be given any additional (or replacement) straws.

Check for Understanding

Have students answer the following questions in their teams or as a whole group discussion.

- Did your bridge meet all of the minimum requirements?
- If you had more time to make another bridge or change yours, would you do anything differently? If yes, what?
- What part of today's activity was the most challenging for your group? Why?
- Can you think of any other places where you have seen truss patterns used for strength?
- What are some things engineers must consider when designing and building bridges?
- Would you consider a career as an engineer? Why or why not? What do you think you would have to study in school?

What's Happening

Triangles are structurally the strongest shape because they allow weight to be evenly spread throughout a structure, allowing it to support heavy loads. Truss patterns are used in structures other than bridges when strength is a priority, such as on roofs, floors, ceilings, radio towers, crane arms, bicycle frames and many other places.

Differentiated Instruction

- For lower grades, allow students to include intermediate supports in the "water."
- For older or more advanced students, have them design and build a straw bridge that spans a distance of 50 cm using the same amount of material with no intermediate supports in the "water."

Extensions

Bridges built in the real world have to stay within budget. Have each of the supplies worth a particular amount and ask students to build their bridge staying within their allotted budget.

Lesson adapted from Integrated Teaching and Learning Program, College of Engineering, University of Colorado at Boulder

NEWSPAPER TENTS

AT A GLANCE

Students become engineers as they build a tent from newspapers and learn what shapes make structures strong.

OBJECTIVES

Students will:

- Learn how shapes help determine the structural integrity of a structure
- Work as a team to build a successful structure

RUN TIME

60 minutes

KEY VOCABULARY

Civil Engineer

Next Generation Science Standards

Science and Engineering Practices:

- Asking Questions and Defining Problems
- Developing and Using Models
- Planning and Carrying Out Investigations
- Using Mathematics and Computational Thinking
- Constructing Explanations and Designing Solutions
- Obtaining, Evaluating and Communicating Information

Crosscutting Concepts:

- Patterns
- Scale, Proportion, and Quantity
- Structure and Function

Disciplinary Core Ideas:

- ETS1: Engineering Design
- ETS 2: Links Among Engineering, Technology, Science and Society

ADVANCE PREPARATION

- Tell students in advance to bring in old newspapers (about two full papers per student).
- Determine how you will divide students into groups of three or four.
- Create a triangle and a square out of rolled up sheets of newspapers (see Warm Up).

MATERIALS

Per Group:

- Lots of newspaper (about two full papers per student)
- Masking tape or duct tape
- Stapler
- Pipe cleaners
- Craft sticks (optional)

NEWSPAPER TENTS

What You Need to Know

Triangles are the strongest shape. Even under enormous pressure from forces, such as tension and compression, triangles keep their shape. This is why civil engineers, people who design structures such as roads, bridges and skyscrapers, and supervise their construction and inspection, often use them in buildings and other construction projects that need to withstand a lot of force.

One of the most common uses of triangles is in the frame of buildings. Look at a building construction site and you will see triangles all over the place. The John Hancock Center in Chicago is a great example of a triangle frame; you can see the triangles on the outside of the building. Triangles are also used in certain types of bridges, called truss bridges. These bridges are made out of inter-connecting triangles and they are able to support a lot of weight. An example of a triangle design from ancient times is the pyramid, such as the Great Pyramid at Giza. The pyramid shape is made out numerous blocks that are stacked in a way to form triangle sides. These pyramids have remained standing strong after thousands of years.

Warm Up

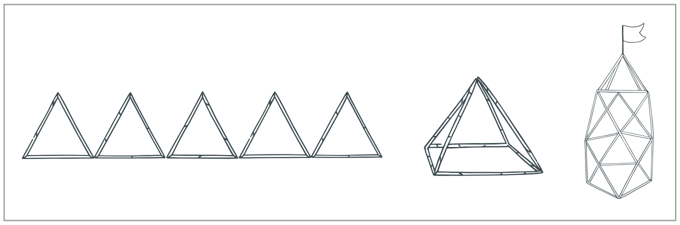
1. Use rolled up newspaper sheets to create an equilateral triangle and a square. Create each one using two sheets of flat newspaper. Use open, two-page spreads, not single sheets. Roll them tightly from corner to corner — the tighter the roll, the stronger the support. Secure the ends with tape. Ask students which shape is stronger, and why.
2. Demonstrate that the triangle is stronger by applying a small amount of force to each shape. Triangles are the strongest shape because any force applied is spread evenly through all three sides.
3. Show students pictures of triangles in structures, such as bridges, skyscrapers, ceilings, and radio towers.

Activity

1. Tell students they will create tents using newspapers.
2. Divide students into groups of three or four.
3. Have each group create 37 newspaper rolls. They will create each one using two sheets of flat newspaper. Use open, two-page spreads, not single sheets. Roll them tightly from corner to corner — the tighter the roll, the stronger the support. Secure the ends with tape.
4. Each group will then use their newspaper rolls to create 11 triangles. They will attach corners together with staples. Note: The last four newspaper rolls will be used to brace their tent.
5. Have them prepare the base of their tent by laying five triangles flat on the ground so that a side of each triangle forms a line. Have them attach the triangles to together along the bottom edge with staples and/or tape. Have them prepare the middle layer by attaching four triangles to each other in the same way.
6. Instruct the students to make a pyramid for the top by attaching the last two triangles at their tops, opposite each other, and using two straight newspaper rolls to complete the square base.
7. Have someone from each group hold things in place as they get ready to erect their tent! Take the bottom layer of five triangles and form them into the shape of a pentagram and staple the last two bottom corners together. The triangle points should stand upward somewhat but will tend to fall over, and that's OK.
8. They will then take the middle layer of four triangles and position them on top of the bottom layer so that the bottom corners touch the pointed tops of the layer below. Twist pipe cleaners around each spot where the two layers join. As they work your way around, the tent should be more upright.

NEWSPAPER TENTS

9. Have them place their pyramid on top and attach at the corners with pipe cleaners. Use tape to secure the last two newspaper roll braces diagonally from the top layer, forming a diamond-shaped door. The tent should be sturdy, but feel free to add tape or even craft sticks to reinforce any wobbly corners.



Check for Understanding

Have students answer the following questions in their teams or as a whole group discussion.

- What is the strongest shape? Why?
- Ask students how they made their newspaper tent strong?
- How could they make it even stronger?

What's Happening

Triangles are considered the strongest shape, because they can handle heavy loads without collapsing. This is exactly why engineers use them in structures. Many bridges, for example, are made up of trusses, which is a series of triangles connected together. Look for triangles the next time you see a bridge or building under construction.

This tent is similar to a geodesic dome, which is a spherical or partially spherical structure formed from triangles. Geodesic domes can be found on playgrounds as climbing structures. Another example is the giant sphere at Epcot.

Differentiated Instruction

- Let students discover what the strongest shape is on their own. Before doing the Warm Up or the Activity, give each group a couple sheets of newspaper and some tape. Have them experiment with various shapes and thickness by folding, rolling, and reinforcing their newspaper so it does not collapse as easily. When they are finished, give each group an opportunity to share their results. Facilitate a discussion about their shapes. Do the Warm Up demonstration and discuss why triangles are stronger.
- Assign each group member a specific job to facilitate teamwork. For example, one person can be in charge of the tape, and another person can be in charge of the stapler or pipe cleaners.

Extensions

- Facilitate creativity by letting students cover their tents with sheets of newspaper, designing a flag for the top, etc.
- Have students brainstorm a way to test the strength of their tents.
- According to the Environmental Protection Agency, paper makes up nearly 30 percent of all waste in America each year. Recycling saves trees, energy, and money, and it reduces waste and reduces climate change.

FORCES

AT A GLANCE

Students work in engineering teams to design, build and test model bridges as they determine how shapes affect the strength of structures.

OBJECTIVES

Students will:

- Describe the structural forces that act upon an object.
- Determine which materials withstand the most compression and tension.
- Explain live and dead loads.

RUN TIME

Two 30-minute periods

KEY VOCABULARY

Structure, Compression, Tension, Bending, Torsion, Load, Live Load, Dead Load

Next Generation Science Standards

Science and Engineering Practices:

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Constructing explanations and designing solutions
- Obtaining, evaluating and communicating information

Crosscutting Concepts:

- Cause and effect
- Energy and matter

Disciplinary Core Ideas:

- PS3: Energy
- ETS1: Engineering design
- ETS 2: Links among engineering, technology, science and society

ADVANCE PREPARATION

- Collect a wide variety of materials on which the different structural forces can be tested.

MATERIALS

Per group:

- Chair
- Scissors
- Samples of six to eight different materials, such as yarn, craft sticks, straws, pipe cleaners, clay, rubber bands, pencils, etc.
- A piece of cloth or rag

Per student:

- Student worksheet

FORCES

What You Need to Know

There are a variety of forces at work in structures. A force is a push or a pull that transfers energy into an object. Structures are subjected to both internal and external forces that need to be considered by engineers and architects as they design safe and lasting structures.

Compression is a force that pushes or squeezes materials. A material under compression may be shortened or crushed. Tension is a force that pulls and/or stretches materials. When a material is bent, one side is in tension while the other is in compression. Engineers must either prevent bending in their structures or select materials that can withstand both tension and compression. Two other important forces acting upon structures are shear and torsion: shear is a force that causes parts of a material to slide past one another in opposite directions, and torsion is a twisting force.

The weight of a structure is referred to as its load. Dead load is the weight of the structure itself (the walls, floors, windows, internal beams, etc) acting with gravity on the foundations below. Live load is the weight that is added to the structure, such as furniture or people, and also the more temporary external forces of wind, snow, earthquakes and traffic. This load changes over time.

Different materials have different abilities to withstand these forces. Understanding which materials best withstand each force is critical when designing structures. Materials that serve as horizontal parts of structures, such as floors and bridge decks, should be able to withstand bending. Materials that are vertical parts of structures, such as walls and bridge abutments, should be able to withstand compression.

Warm Up

1. Place a chair in the middle of the floor. Are there any forces acting upon it?
2. Gently push the chair a long distance. What forces acted upon the chair? A push created an unbalanced force that made the chair move.
3. Repeat this last step, this time having a second person pushing back on the chair so that it does not move. What forces are acting on the chair? Why does it not move? Two forces are acting on the chair, but they are balanced. Ask the students to think back to the first step. When no one is pushing on the chair are there still equal forces acting upon it?

Explain to the students that in any building, from a house to a skyscraper, there are forces acting upon it. Ask the students if they know what a force is. When talking about structures, a force can be defined as a push or a pull. There are a few main forces that act upon every structure.

<u>Tension</u>

1. Give each student a rubber band. Tell them to pull the rubber band with their hands. What happens? It stretches out, gets longer and the material gets thinner. The rubber band is being pulled; this is called tension.
2. Have two students link fingers and lean away from each other. How do their arms feel? Do they feel stretched? Tension is the stretching force that pulls on a material.
3. Can you name parts of structures in the real world that are under tension? Elevator cables and the cables on suspension bridges are parts of structures that are in tension.

<u>Compression</u>

1. Show the group a large sponge. Pass the sponge around and have a few students push down on top of the sponge. Ask them: What happens? The sponge gets smashed down, it gets shorter, and it bulges in the middle. The sponge is being pushed or being compressed.

2. Have two students place their palms together and gradually lean in toward each other. How do their arms feel? Do they feel squeezed or pushed together? Compression is the pressing force that squeezes a material together.
3. Can you name parts of structures in the real world that are under compression? Columns and bridge abutments are parts of structures that are under compression.

Activity

<u>Torsion</u>

1. Have two students grab the opposite ends of a piece of cloth, and start turning that cloth in their hands in opposite directions from one another. What happens to the cloth? Torsion is the twisting force that acts upon structures.
2. Can you predict what would happen to a bridge deck under torsion?

<u>Load</u>

1. Have students look around the room and make a list of all the different loads that they can find.
2. As a class, make a T-chart dividing the lists of loads into two categories: dead loads and live loads. Dead loads include the weights of the walls, ceiling, floor and any permanent structures such as light fixtures, doors and windows. Live loads include things that are not fixed, such as furniture, pictures, people and the rain or snow that might be pounding the building outside.

<u>Materials' Strength</u>

1. Give each group of students six to 10 samples of various materials.
2. Ask students to predict which materials will best be able to withstand tension, compression and torsion.
3. To test tension, pull on the object from each end.
4. To test compression push the object from each end.
5. To test torsion, grab each end of the object and turn it in opposite directions (twist it).
6. Which materials withstood the forces best? Which ones broke easily?
7. Can you think of a material that would be able to withstand both tension and compression?
8. Does the shape of the material impact how strong it is? Try adapting an object to test this.

Check for Understanding

Have students answer the following questions in their teams or as a whole group discussion.

- What types of forces act upon a structure?
- Why is it important to use the right material to build a structure?
- What is the difference between live and dead load?

What's Happening

Forces (like tension and compression) that work on a building need to be equally distributed throughout the structure. This means the building must have a strong foundation and use strong shapes throughout.

Shapes like triangles are very strong because they distribute weight evenly from the points to the base. Triangles also keep their shape even under enormous pressure.

Differentiated Instruction

For English learners, build a word wall with the vocabulary words for this lesson. Have students create their own flash cards with the definition of the term on one side, and a drawing of it on the other.

FORCES

Extensions

- Sometimes the forces acting upon a structure are stronger than the structure itself. Research structures that have been unable to withstand the forces exerted on them. What happened? Was the structure re-built? If so, how was the design of the structure changed to made it more structurally stable?
- List the materials from the Materials' Strength section according to whether they were good under compression or good under tension. What do all the tension materials have in common with each other? What do all the compression materials have in common with each other? What characteristics do the materials from both groups share? Construct a Venn diagram to answer these questions.
- Look at pictures of various buildings and have the students draw or tape "Force Arrows" for tension, compression and torsion to show where forces are acting on each one.

Forces Student Worksheet

Name ________________________________

1. What is the main effect of tension on a material?

____

2. What are some parts of real world structures that are under tension?

____

____

3. What is the main effect of compression on a material?

____

4. What are some parts of real world structures that are under compression?

____

____

5. What force is acting upon the cloth that was twisted?

____

6. Can you predict what would happen to a bridge deck under torsion?

____

____

7. What force is exemplified by scissors? Briefly explain the interaction of forces that make a pair of scissors work.

____

____

____

8. Make a list of all the different loads you can find in your classroom, and circle if it is a “dead” or “live” load.

Load ______________________________	DEAD LOAD	LIVE LOAD
Load ______________________________	DEAD LOAD	LIVE LOAD
Load ______________________________	DEAD LOAD	LIVE LOAD
Load ______________________________	DEAD LOAD	LIVE LOAD
Load ______________________________	DEAD LOAD	LIVE LOAD
Load ______________________________	DEAD LOAD	LIVE LOAD
Load ______________________________	DEAD LOAD	LIVE LOAD
Load ______________________________	DEAD LOAD	LIVE LOAD
Load ______________________________	DEAD LOAD	LIVE LOAD
Load ______________________________	DEAD LOAD	LIVE LOAD
Load ______________________________	DEAD LOAD	LIVE LOAD
Load ______________________________	DEAD LOAD	LIVE LOAD

Forces Student Worksheet

Name ___________________________

9. List materials that are strongest in each of these forces:

TENSION	COMPRESSION	TORSION

10. Which materials withstood the forces best? Which ones broke easily?

____

____

____

11. Can you think of a material that would be strong in both tension and compression?

____

____

____

12. Does the shape of the material impact how strong it is? Try adapting an object to test this.

____

____

____

FACILITATED EXPERIENCES

EDUCATIONAL PROGRAMMING SUMMARY

In this section you will find two programs that put participants into the shoes of architects, urban planners, and designers. Both activities are scalable to your needs and, while designed for children ages 8-12, can be enjoyed by audiences of all ages. The summaries, outlines, and supporting materials are provided as a starting point for you to create your own experiences.

Mini Metropolis

In Mini Metropolis, participants will think like urban planners and determine the needs of the city and then create the necessary structures out of everyday materials to help this miniature city grow. They will discover that planning is an important part of creating a healthy, functional environment that people want to live in.

This program can be easily adapted to any size space or environment by adjusting the size of the city layout, plots and building materials.

Design Challenge

The Design Challenge experience revolves around participants thinking like architects, engineers, and designers, and using LEGO® bricks to create a solution to 1 of 5 challenges. The Design Challenge has 3 different versions, a more formal show, a more informal lab or classroom style experience, and a shorter engagement that can be used in free build areas. In all the versions, the participants will have to consider and share the aesthetics, function, and innovation behind their creations.

In the formal show, 2 competitors have 5 minutes to build a model of their invention with LEGO bricks that would solve that show's challenge while the audience judges their creations based on themes of aesthetics, function, and innovation. For the lab or classroom setting, teams of participants work together to draw up a blueprint, use LEGO bricks to build a model of their design, and share it with the rest of the group. In the open build engagement, participants build creations and are encouraged to discuss what they created. Facilitators can then draw connections to the themes of aesthetics, function, and innovation.

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MINI METROPOLIS

FACILITATION SPACE

50 ft by 50ft space (can be adjusted for smaller locations).

STAFFING LEVEL

1-2 Facilitators

RUN TIME

Approx 10-12 min

TARGET AUDIENCE

8-12

GOALS

Participants will learn that urban planners make cities functional and healthy places to live by deciding what to build in a city and where to build it.

Participants will discuss their thinking behind the structures that they create for the city.

In Mini Metropolis, participants will think like urban planners as they build structures to add to a city and discover that planning is an important part of creating cities that people want to live in.

INTRODUCTION Before participants get their materials

1. Welcome participants and introduce the engagement

   "Hello everyone. Welcome to Mini Metropolis. Today we are all working to create a city. In order to create our city, we are going to have to think like urban planners."

2. Ask participants a few questions to start discussing urban planning. Be sure to share a definition of what an urban planner does.

   "To get started let's make some observations. What do you notice about our city right now?"

   - **Use participants' observations to point out what is currently in the city.**

   "What do think our city still needs if it is going to be a place people want to live?"

   - **Use participants' answers as a jumping off point to discuss the types of building/structures that urban planners make sure a city has.**
   - **Housing, schools, fire/police, electricity, water, cultural institutions etc.**

   "This is part of what urban planners do. They make sure that our cities have everything people need to live happy and healthy lives."

3. Ask participants a few questions to transition them to discussing what they want to add to the city. Share that urban planners make decisions about both what structures go into a city and where they should be.

   "What do you want to create for our city?"

   - **Have participants try to articulate what they want to build. If they don't know yet that's okay though.**

   "In addition to determining what structures a city might need. Urban planners also make decisions about where in the city those structures should be."

   "Where do you think your "structure" should go in the city? Why?"

   - **Share the content to reinforce or redirect participants' choices.**

MINI METROPOLIS

MATERIALS

- City Layout with City Plots (see support materials for example)
- Build Tables (based on expected group/space size)
  - Each build table should have: Chairs and recommended building tools [Scissors, glue, markers or other coloring supplies, masking tape (colored masking tape allows for building and decorating)]
- Supply Tables (based on expected group/space size
- Recommendations crafting Supplies below:
  - Construction paper and vinyl, felt squares, foam core, rubber bands, spangles, craft sticks, cardboard and plastic tubes, tiny architecture model people, any other miscellaneous small and large craft or scrap items
  - Variety of sizes of cardboard boxes for structure bases (5x5x5, 7x5x5, 7x3x2, cereal, tissue boxes)

4. Give participants instructions and have them start building their creations.
   - Grab a plot of land
   - Use the supplies and building space provided to build your structure
   - If you need any help, reach out to one of our facilitators
   - Once you've finished your creation, add it back into the city

ACTIVITY — While participants are building

1. Ask participants open ended questions to encourage them to talk about their creations and communicate their choices. Don't make assumptions about what a participant is building; ask them.
   - What have you created?
   - What are you building?
   - What you working on?
   - Why did you choose this material to work with?
   - This looks cool. What part of the city is it going to be?
   - Why did you decide to build a [answer from a previous question]?

CONCLUSION — When participants add buildings into the city

1. When participants finish their creation encourage them to add it to city and discuss why they made the choices they made.
2. Celebrate what they built and how they are thinking like urban planners.

   "Let's add you creation back into the city. What did you create? Why do you think the city needs your structure?

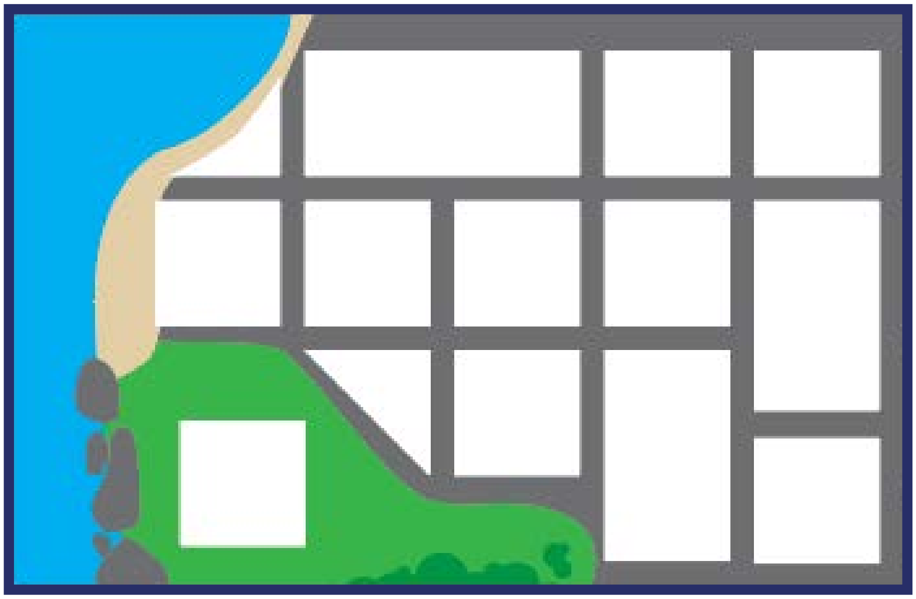
   Great job! You helped us create a city where people want to live! Just like an urban planner you thought about what our city needed and also how all the parts of the city work together to make it good place to live!

   Thanks so much for helping us out and have a good day."

MINI METROPOLIS

SET UP

- **Set up City Layout**
  - To create your city layout you can either print out the provided design, draw a layout by hand, or create one using masking tape.
  - The City Layout map can be set up either on a floor, table, or stage; depending on your program's needs.
  - Fill your city layout with "city plots" that the participants will use as bases to build on. These can be cardboard squares or any other sturdy material.
- **Set up Build Tables**
  - It is recommended that each Build Table has one set of building tools and enough open workspace for at least 1 family to build on.



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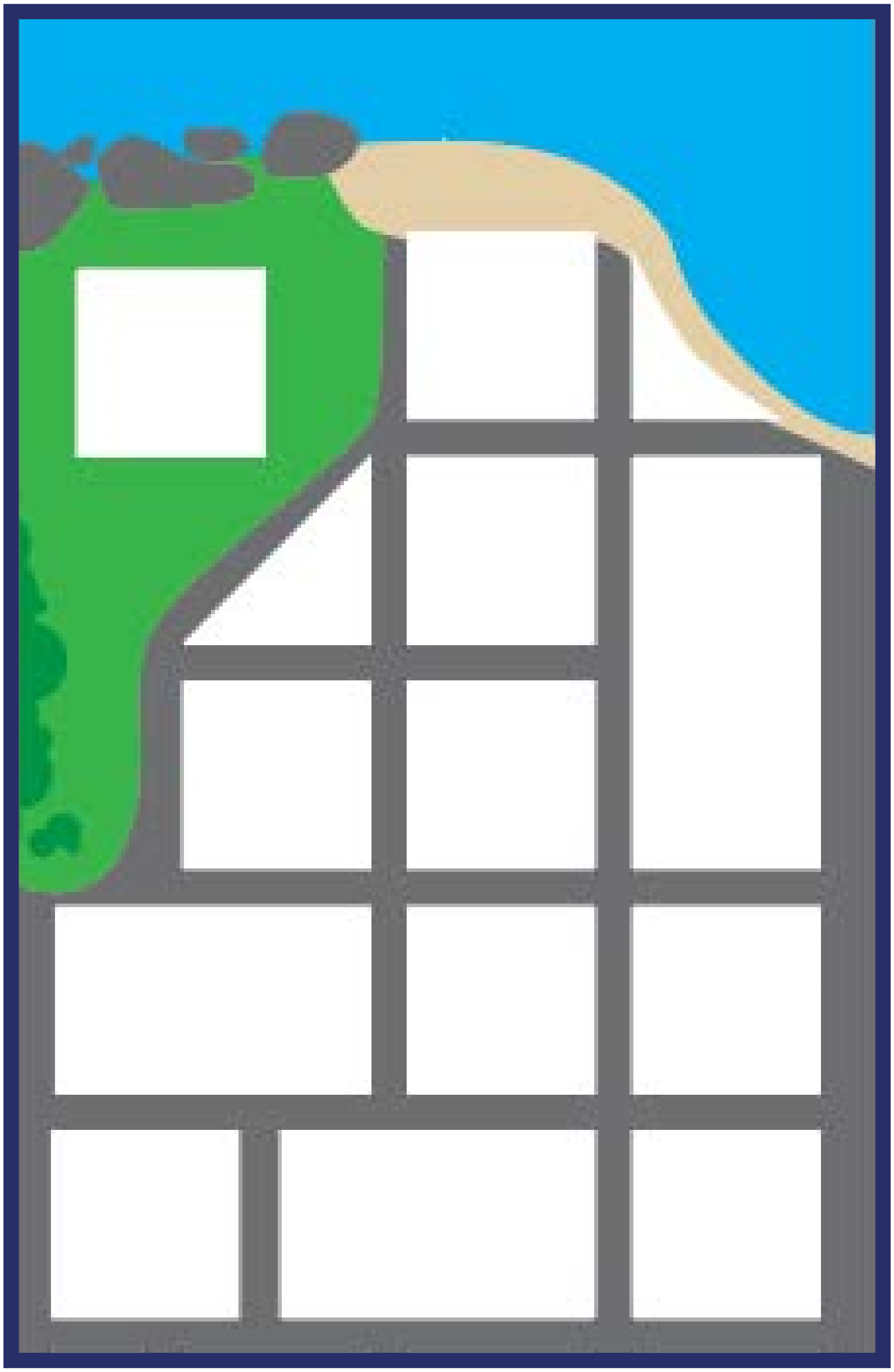
SUPPORT MATERIALS

City Layout



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DESIGN CHALLENGE

FACILITATION SPACE

Lab/Classroom, stage or open build area, depending on program version.

STAFFING LEVEL

1 person

RUN TIME

Approx 5 to 20 min

TARGET AUDIENCE

8-12

GOALS

Participants will learn that designers are involved in all areas of our lives. They imagine a better future and build it.

Participants will learn that good design considers aesthetics (how something looks), function (how something works) and innovation (how something is different from what existed before).

The Design Challenge encourages participants to think like Architects, Engineers, and/or Designers by using LEGO bricks to create possible solutions to challenges we face throughout the world. This program has 3 different deliverable options that share the same goals. Below are the descriptions of each option from a very informal mini engagement to a presentation style show format.

OPTION 1 Open Build Mini Design Challenge Experience

In this informal setting, participants will create anything they're inspired to build. A program facilitator is not needed; however, the experience can benefit from one being present. The facilitator would occasionally chat with participants, asking them questions about what they're building and encourage them to continue expanding their creativity.

OPTION 2 The Design Challenge Lab Experience

This is a cooperative, lab-based experience in which a facilitator guides teams of participants to work together to draw up a blueprint, use LEGO bricks to build a model of their design, and share it with the rest of the group.

OPTION 3 The Design Challenge Show Experience

This a facilitated "competition-based" show in which 2 competitors have 5 minutes to build a model of an invention that would solve a challenge faced by people around the world. The audience will judge their creations based on themes of aesthetics, function, and innovation.

OPTION 1: OPEN BUILD

MATERIALS

- LEGO bricks (suggested 5,000 though depends on size of your space)
- Bins/Boxes for LEGO bricks
- Build tables
- Optional display table/space
- Optional: Challenge cards (see support materials) if participants are interested you can use the challenge cards to set build challenges. The same engagement works to discuss build challenge builds as free builds.

SET UP

- Create a free build area where participants can explore their creativity by using LEGO bricks to design anything that comes to mind. This area does not require facilitator/ participant interaction; however, it can benefit from this mini engagement.
- Check if build boxes are well stocked
- Clear off build table
- If using a display table and it is getting full, disassemble LEGO bricks on display.

Facilitation Outline

1. Approach a participant building in a free build area.
2. Ask the participant questions about what they are building.

   Examples:
   - **"What are you building?"**
   - **"What have you created?"**

3. Once you know what the participant is building, follow up with specific questions. Relate participant answers to aesthetics, function and innovation.

   Examples:
   - **"What does this part do?"**
   - **"Why did you choose this piece?"**

4. Connect the process of building to the work of architects, engineers and designers using the 3 design principles of aesthetics, function and innovation.

   Example:
   - **"Nice. You are thinking about how your spaceship works or its function. That's one of the things architects, designers and engineers think about whenever they create something new."**

5. Encourage other participants to build as well.

OPTION 2: LAB BASED

MATERIALS

- 4 boxes of LEGO bricks
- Challenge cards (see support materials)
- 2 Countdown timers
- Pencils
- Paper

SET UP

- Check that the 4 boxes of LEGO bricks are equally filled.
- Put 3 minutes on one of the countdown timers and 5 minutes on the other countdown timer.
- Make sure the tables are arranged with 4-5 pencils and paper at each table.
- Put the five design challenge cards in your pocket.

POST-SHOW PROCEDURES

- Clean LEGO bricks off of build tables and put back in the design boxes.
- Replace the paper and sharpen the pencils.

Facilitation Outline

1. Introduce the program and yourself:

   "Hello everyone and welcome to the Design Challenge Lab. My name is [Facilitator name]."

2. Set expectations for program:

   "Over the next twenty minutes, we are going to think like architects, engineers and designers and invent solutions to a real-world design challenge."

3. Explain that designers, architects and engineers are involved in all areas of our lives:

   "Designers, architects and engineers are involved in all areas of our lives: from designing buildings to creating a new tool for eating spaghetti."

4. Explain the build challenge:

   "On these cards I have real-world build challenges that architects, engineers and designers are working on right now. In a moment we will choose a challenge. Then each table will work as teams to invent some amazing solutions to that challenge and build them out of LEGO bricks. After that you all will have the opportunity to share your designs with the group."

5. Introduce the three design factors:

   "In order to create our solutions, we all need to think like architects, engineers and designers. No matter what they are inventing, architects, engineers and designers think about these three factors."

   Explain the three design factors

   - **Aesthetics – what an object looks like.**
   - **Function – how an object works.**
   - **Innovation – what sets an object apart from what already exists.**

   "Aesthetics, Function and Innovation are the three factors we will be thinking about as we find solutions to the build challenge."

6. Pick the build challenge:

   "Now it is time to reveal the design challenge. Here I have some real-world design challenges."

   - **Show the audience the design challenge cards.**

- Have a member of the audience pick one design challenge card and hand it back to you.
- Read the challenge card to share the design challenge with the audience.
  "Our design challenge is…"

7. Introduce Planning Time

   "Now that we have the design challenge of [design challenge], you all will have 3 minutes to plan your team's design. After this planning time you will have just five minutes to build your design using the LEGO bricks in these boxes. At your tables are pencils and paper to help you plan. Any questions? Begin planning [design challenge]."

8. Start 3 minute planning time
   - During planning time wander between groups. Ask teams questions about the aesthetic, functional and innovative qualities of their designs. Do not assume any element of the team's design; just ask them about it.
   - Give teams a one minute warning.

9. End planning time and start build time.

   "Teams, your planning time is up! Set your pencils down. Now each team is going to receive one box of random LEGO bricks. Your mission is build your design in five minutes using these LEGO bricks.

   Before we begin do you have any questions?"

   - Answer any questions.
   - Check that timer is set for 5 minutes.
   - Countdown to start of build time.
   - Start timer and tell builders to begin building.

10. Build Time
    - Give teams a 3 minute warning.
    - Give teams a 1 minute warning.
    - During build wander between the teams and ask open ended questions about their designs related to aesthetics, function and innovation. Don't make assumptions about the design.

11. End build time and celebrate the designers' new inventions:

    "Designers put your last piece on your creation and step back. Now let's see your awesome designs!"

    - Celebrate the fact that these brand new designs were built in five minutes and give the teams a round of applause.

    "Now that you have built your amazing designs, take a moment to name your creations."

OPTION 2: LAB BASED

12. Ask teams to share their designs:

    "[Team 1] what have you built to help [design challenge]?" If teams gives one short answers ask a follow up question about aesthetics, function or innovation.

    - **Positively reinforce answers and share with audience.**
    - **Repeat for each team**

13. Relate the design challenge to current challenges today:

    "We just tested our design skills and invented solutions to the real-world challenge of [design challenge]. In less than 10 minutes we came up with some great designs. Designers, architects and engineers around the world are working on solutions to this challenge as well.

    "The work of architects, engineers and designers is all around us from designing [design challenge] to inventing the next [participant's object]. We created some awesome designs today in just a few minutes. Now imagine what you could design in an hour, a day, a year. Thank you all for coming to the Design Challenge Lab today, and if you have any questions or want to see the designs up close feel free to come up and ask."

OPTION 3: FORMAL SHOW

MATERIALS

- Small Containers of LEGO bricks (suggested approximately 100 LEGO bricks per box)
- Challenge cards (see support materials)
- Countdown time

SET UP

- Check that you have a variety of unused LEGO brick containers for participants.
- Put 3 minutes and 30 seconds on the countdown timer.
- If saving participants' designs, make space near the front of the display space for the two new designs.
- Put the five design challenge cards in your pocket.

Facilitation Outline

1. Introduce the show and yourself:

   "Hello everyone and welcome to the Design Challenge. My name is [Facilitator name]."

2. Set expectations for show:

   "Over the next ten minutes, we are going to think like architects, engineers and designers and invent solutions to a real-world design challenge."

3. Explain that designers, architects and engineers are involved in all areas of our lives:

   "Designers, architects and engineers are involved in all areas of our lives: from designing buildings to inventing an improved tool for eating spaghetti."

4. Explain the design challenge:

   "On these cards I have real world design challenges that architects, engineers and designers are working on right now. In a moment we will choose a challenge and then we will invent some amazing solutions to that challenge. After that you all will have the opportunity to award our designers a [Exhibit Name] Design Award."

5. Pick the 2 volunteers to be the designers:

   "Before we pick our challenge, I am going to need 2 volunteers to join me up on stage and be our designers. As designers, you will build a solution to a real-world design challenge using LEGO bricks."

   - **Bring volunteers up on stage and have audience give them a round of applause.**
   - **Have the volunteers stand on either side of stage behind the build tables.**
   - **Get the volunteers' names.**

6. Set expectations for the design challenge:

   "Designers [volunteer names can be used instead of designers], you will have three and a half minutes to build a solution to the design challenge. As audience members, you will want to check out our designer's inventions as they build because you will have the opportunity to award our two amazing designers a Design Award once they finish building."

7. Introduce the three design factors:

   "Whether you are in charge of building or giving an award, we all need to think like architects, engineers and designers. No matter what they are inventing, architects, engineers and designers think about these three factors."

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OPTION 3: FORMAL SHOW

POST-SHOW CLEAN-UP PROCEDURES

- Clean LEGO bricks off of build tables and put back in the design boxes.
- Put used design boxes on designated shelf.
- Replace the used design boxes with unused design boxes.

POST-SHOW RESTOCKING

- After the last show of the day, break down the LEGO brick creations that were created that day and remake LEGO brick designer boxes. Each box should have approximately 80 pieces and have a variety of pieces.

Explain the three design factors

- Aesthetics – what an object looks like.
- Function – how an object works.
- Innovation – what sets an object apart from what already exists.

"Aesthetics, Function and Innovation are the three factors we will be thinking about as we find solutions to the design challenge."

8. Have volunteers pick out their LEGO building supplies:

   "Before our designers get started building, they need something to build with. On the wall behind me are boxes of LEGO bricks. Each box is different. Designers, you are going to have just ten seconds to pick one box of supplies and bring it back to your table. Builders are you ready to pick your bricks? 3,2,1 Go."

   - Build tension with audience by commentating while volunteers pick.

9. Pick the design challenge:

   "Now that our designers have picked their supplies, it is time to choose the design challenge. Here I have some real-world design challenges."

   - Show the audience the design challenge cards.
   - Have a member of the audience pick one design challenge card and hand it back to you.
   - Read the challenge card to share the design challenge with the audience.

     "Our design challenge is…"

10. Start the design challenge:

    "Alright designers now you will have three and a half minutes to build something to help [design challenge]. Before we begin do you have any questions?"

    - Answer any questions.
    - Check that timer is set for 3 minutes and 30 seconds.
    - Have audience countdown to start of build time.
    - Start timer and tell builders to begin building.

    "Our designers are starting to build. They are working on solutions to a very specific challenge, [design challenge] but designers are involved in all parts of our lives."

11. Have a discussion with the audience while the volunteers build:

    "Think about an object you touched before you visited us today. What object are you thinking of? Shout it out."

    - Positively reinforce answers.
    - Choose one answer to build the conversation on.

OPTION 3: FORMAL SHOW

- Follow up by asking questions about the object's design…
  - What challenge is [participant's object] a solution to?
  - What about the [participant's object] design helps it function as a [previous answer]?
  - If you saw 100 different [participant objects] on wall, what about [the objects] would make you pick one out?
  - Connect answers to aesthetics, function or innovation
  - If you were going to invent the next new [participant object], what would you include in the objects design to make it innovative, different from what came before?

12. Check countdown clock and at 1 minute or less check in with the builders:

    "There are only [minutes left to build] left for our designers to complete their solutions to the challenge of [design challenge]. Let's see how they are doing."

    - Ask volunteers, "How are you doing?"
    - Provide positive reinforcement on volunteers' designs design so far.

13. Check countdown clock again and at less than 30 seconds prepare audience for the end of build time:

    "Alright everyone, our designers have less than 30 seconds left to build. Once they finish building we will have a chance to see the amazing designs they have created to [design challenge]. You all will also have a chance to use what we learned about aesthetics, function and innovation to give our builders a [Exhibit Name] award. Builders you have just 15 seconds left."

    - Involve audience in the countdown.

14. End build time and celebrate the designers' new inventions:

    "Designers put your last piece on you creation and step back. Now let's see your awesome designs!"

    - Celebrate the fact that these brand new designs were built in three and a half minutes and give the volunteers a round of applause.

15. Ask builders share their designs:

    "[Volunteer 1] what have you built to help [design challenge]?" If the volunteer gives a one-word answer ask a follow up question about a specific part.

    - Positively reinforce answers and share with audience.

    "[Volunteer 2] what have you built to [design challenge]?" If Volunteer gives one word answers ask a follow up question about a specific part.

    - Positively reinforce answers and share with audience.

OPTION 3: FORMAL SHOW

16. Reiterate the three award categories while the volunteers think of names for their designs:

    "[Volunteer 1 and 2], take a moment to think of a name for your design. Now it is time for us to give our amazing designers a [Exhibit Name] Design Award. The three award categories are the three factors of design we talked about earlier, aesthetics, function and innovation. The aesthetics award for a cool looking design. The function award for a cool working design. The innovation award for a design that is different for anything you have seen before. We will introduce each design and then you all will have the opportunity to vote on which award you want to give to the design."

17. Have the audience give each volunteer a Design Award:

    "Up first is…"

    - **Present Volunteer 1 and his/her creation.**

    Ask for name of creation.

    - **Share the categories for the award.**
      - **Aesthetics**
      - **Function**
      - **Innovation**
    - **Have audience vote by holding up 1, 2 or 3 fingers or another method.**
    - **Repeat for Volunteer 2.**

    Example: "Kate, what is your design called? Kate had built The Amazing Water Motorcycle! Now it's time to vote. Hold up one finger if you think Kate should receive the aesthetics award, two fingers for the function award or three fingers for the innovation award."

18. Celebrate the builders' designs and wrap-up:

    "Congratulations [Volunteers' names]! You have received the awards in [voting results]. Everyone give our designers a round of applause. We are going to proudly display your new never before seen designs here on the Design Challenge Stage for the rest of the day."

    "We just tested our design skills and invented solutions to the real-world challenge of [design challenge]. In less than four minutes we came up with some great designs. Designers, architects and engineers around the world are working on solutions to this challenge as well.

19. Conclusion:

    "The work of architects, engineers and designers is all around us from designing [design challenge] to inventing the next [participant's object]. We created some awesome designs today in just a few minutes. Now imagine what you could design in an hour, a day, a year. Thank you all for coming to the [Exhibit Name] design challenge today and if you have any questions or want to see the designs up close feel free to come up and ask."

SUPPORT MATERIALS

Challenge Cards

DESIGN CHALLENGE

Build something to help you around the house

DESIGN CHALLENGE

Build something to help you live on water

DESIGN CHALLENGE

Build a new way to travel to another country.

DESIGN CHALLENGE

Build something to help you survive in the desert

DESIGN CHALLENGE

Build a new way to get to school or work

DESIGN CHALLENGE

Build something to protect people from extreme weather

DESIGN CHALLENGE

Build something to help scientists study animals underwater

DESIGN CHALLENGE

Build something to help you explore another planet

museum of science+industry chicago