General Outline

Skyscrapers

(After-School)

In this 12-week module, students identify the characteristics that make skyscrapers unique and learn how columns and beams work together to support tall structures. For their final project, students work in teams to design and construct a structural grid, then calculate its usable square footage.

Objectives

Students will be able to:

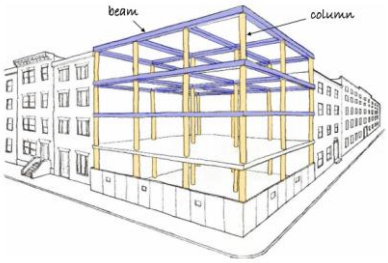
1. increase their understanding of the Built Environment
2. cite characteristics unique to skyscrapers
3. conduct scientific experiments to verify hypotheses and draw conclusions based on evidence
4. calculate square footage as a two-dimensional area
5. manipulate and use basic model making tools such as glue, tape, scissors
6. work in cooperative groups to translate ideas and concepts from a two dimensional design to a three dimensional model

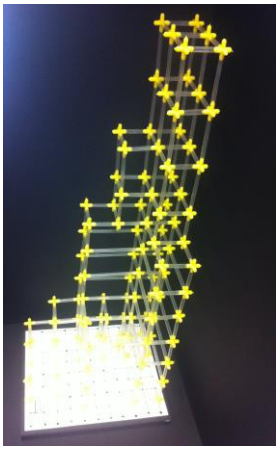
Outline

Session 1	Introduction to Skyscrapers: Sky High Challenge
Session 2	Structural Elements: Columns
Session 3	Structural Elements: Beams
Session 4	Structural Grid and Façades
Session 5	Scale and Square Footage
Session 6	Understanding Proportion
Session 7	Materials Exploration
Session 8	Technology and Introduction to the Design Challenge, Part I
Session 9	Design Challenge. Part 2 - Construction
Session 10	Design Challenge, Part 3- Constructing the Plaza
Session 11	Design Challenge, Part 4- Continue the Plaza Construction
Session 12	Design Edits, Review and Final Presentations

Sample Vocabulary

- **built environment** – everything that is designed and built around us (i.e. houses, bridges, roads, parks, hospitals, schools, churches, etc,)
- **skyscraper** – a contextually tall building that rises well above the other structures around it and changes the skyline
- **structure** – something built or constructed, such as a dam, bridge, or a building
- **structural grid** – a skeletal framework designed to support a building; a structure composed of columns and beams connected to one another
- **façade** – the front or face of a building
- **skyline** –the outline of buildings against the sky; the artificial horizon that a city's overall structure creates. Skylines serve as a kind of *fingerprint* of a city, as no two skylines are alike





salvadori CENTER
see it. build it. know it.

Outline 2 Structural Elements of a Skyscraper: Columns (After-School)

Overview

Students will understand how buildings are supported by a structural grid and a column's shape and height affects its load-bearing capacity.

Objectives — **Students will be able to:**

1. label the components that make up a skyscraper's structural grid
2. predict and test the relative load-bearing capacities of four different shapes of columns: triangular, square, circular and pentagon
3. draw conclusions based on evidence and prior knowledge

20 min. — **Primary Activity Introduction: Structural Grid**

- Discuss and identify two structural members that supports a building
- Illustrate forces on a vertical structure with a foam column
- Structural grid worksheet

45 min. — **Primary Activity: Column Quest**

- Students will make a prediction and brainstorm about which column shape will hold the most weight.
- Groups will create 4 columns of the same shape from 2D to 3D
- Student groups test their column type by loading it from the top.

10 min. — **Extension**

- Students record observations and results of each column tested onto their chart and draw a conclusion.

15 min. — **Wrap-Up:**

- Students share where in the built environment they have seen circular or other column shapes.
- Students suggest how else column strength is affected (e.g. type of materials used, reinforcements applied, carefulness of construction, dynamic force).

Vocabulary

- **buckle:** sudden lateral instability of a slender structural member due to a compressive force along its vertical axis
- **column:** a vertical, rigid, upright structural member designed to carry loads
- **compression:** the act of shortening an object by applying a pushing force: a member in compression gets shorter
- **load:** any forces that act upon a structure; weight
- **tension:** the act of lengthening an object by applying a pulling force: a member in tension gets longer
- **structural grid:** a skeletal framework designed to support a building; a structure composed of columns and beams and connected to one another

Outline 2	Standards Addressed

Common Core State Standards (CCSS)-Mathematics

CCSS.Math.Content.4.MD.A.1

Know relative sizes of measurement units within one system of units including km, m, cm; kg, g; lb, oz.; l, ml; hr, min, sec. Within a single system of measurement, express measurements in a larger unit in terms of a smaller unit.

Next Generation Science Standard (NGSS)

3-5 ETS1 Engineering Design

3-5-ETS1-3 Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Blueprint for Teaching & Learning in the Arts

Art Making (Grade 5)

Sculpture: create a sculpture that demonstrates stable construction of a three dimensional form

Outline 2 Standards Addressed

Common Core State Standards (CCSS)-Mathematics

7.SP.C.6 Approximate the probability of a chance event by collecting data on the chance process that produces it and observing its long-run relative frequency, and predict the approximate relative frequency given the probability.

Next Generation Science Standard (NGSS)

MS-ETS1-3 Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4. Develop a model to generate data for interactive testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

LESSON 2

NOTE: THIS IS LESSON 2 OF A 12- LESSON RESIDENCY

Salvadori After School

Skyscrapers

salvadori CENTER
see it. build it. know it.

Lesson 2 Structural Elements of a Skyscraper: Columns (Afterschool)

Overview

Students will understand how buildings are supported by a structural grid, and how a column's shape affects its load-bearing capacity.

Objectives **Students will be able to:**

1. label the components that make up a skyscraper's structural grid
2. predict and test the relative load-bearing capacities of four different shapes of columns: triangular, square, circular and pentagon
3. draw conclusions based on evidence and prior knowledge

20 min. **Recap and Primary Activity Introduction**

- ***What did we learn about last week? Can anyone explain what the built environment is? What does a skyscraper need to have?***

- Student will explore how Skyscrapers are built.
- Ask students what is the purpose of a person's skeleton. [Possible responses: it keeps us from falling, helps us to stand up, makes us stronger, etc.]

  Our skeleton is our structure – if we didn't have a skeleton, we would just collapse or flop around. Just like humans have a skeleton, a skyscraper has a structural grid that supports the building and keeps it standing.
- Draw students' attention to the Structural Grid poster at the front of the room. *A **structural grid** is a system of columns and beams that are connected to each other. This allows a skyscraper to carry the **loads** (or weights) of all the materials used to build it, as well as the objects and people that will go inside it. We are going to label and color the different parts of the structural grid, and then do an activity where we test them!*
- *A **column** is a vertical structural member designed to carry loads. Which way does vertical go? Who can come up to the diagram and shade in a column for me? Remember – we are going to use a different color (green) to shade the columns.*
- *A **beam** is a horizontal structural member designed to carry and transfer loads. Which direction do I mean when I say horizontal – does that go up and down or side to side? Do you see horizontal components on this diagram? Use the red dry erase marker and color in the beams.*

Lesson Prep

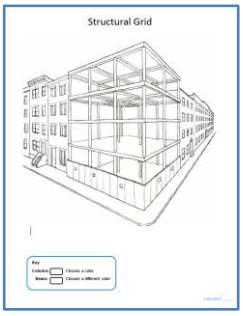
- ✓ Post charts/pictures:
  1. Salvadori Student Agreement
  2. Structural Grid poster
  3. Column Quest poster
- ✓ Prepare sample columns (one of each shape)

Materials

- ☐ stickers, pencils, yellow student folders
- ☐ chart paper
- ☐ vocabulary words - Session 2 (cardstock or 24lb.)
- ☐ 16 red colored pencils
- ☐ 16 green colored pencils
- ☐ dry eraser and dry erase markers (red and green is a must)
- ☐ *Structural Grid* worksheet
- ☐ *Column Quest!* worksheet
- ☐ *Column Quest!* materials (per group)
  - ☐ one 10×10 cardboard base
  - ☐ 4 copies of one template shape per group, on 20lb paper of different colors: triangle (short & tall), square (short & tall), circle (short & tall), pentagon (short & tall)
  - ☐ sixteen 1" pieces of tape
- ☐ *Column Quest* testing materials
  - ☐ one 10×10 cardboard base
  - ☐ weights(about 2 lbs each)
  - ☐ food scale (optional)

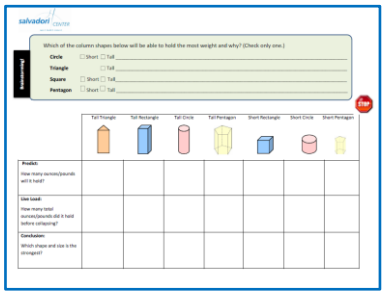
Vocabulary

- ☆ structural grid
- ☆ load
- ☆ column
- ☆ beam
- ☆ dead load
- ☆ live load



Intro to Primary Activity (cont.)

- Have a volunteer shade in a few more columns to ensure their understanding.
- Pass out the Structural Grid worksheet, along with a green or red color pencils to each student. Tell the students to color in the columns if they got a green color pencil and if they got a red pencil to color in the beams on the picture handout.
- Walk around to check students' work, then have students get into their working groups (4-5 students) for the *Column Quest* activity.



Column Quest Worksheet

45 min.

Primary Activity: Column Quest

- Guiding the discussion:

  When architects and engineers are designing a building, they have a lot of options when it comes to style and materials. For example, if they are going to use columns to support the load of a building, they have a choice about whether to use columns shaped like this [hold up the triangular column], *like this* [hold up the square/rectangular column], *like this* [hold up the cylinder/circular column], *or like this* [hold up the pentagonal column]. *If you were an architect, which would you choose?*

  So we're going to investigate whether the shape makes a difference in how strong the column is.

- Give students the *Column Quest!* worksheet and complete the top section, in which they make a prediction about which column shape will hold the most weight. While students are writing their responses, begin distributing materials. Each group gets:
  - 4 identical sheets of one type of column (e.g., triangle)
  - twelve 1" pieces of tape (3 per column) every student gets 3 pieces of tape [ask the teacher to do this part as you give out the handouts]
  - if you are running out of time distribute 2 rolls of tape per group and tell the students that each column only can have three small (1-2 inch) pieces of tape
- Encourage students to share their brainstorming responses.
- Instruct students to begin folding their templates along each of the lines, and then tape together into the shape of a column. Leave the pre-assembled columns out at the front of the room so students can use those as examples of the final product.
- Remind students to build their columns very carefully, and not to handle them too much before testing their strength. This puts stress on the material and may make the column weaker than it would have been otherwise.
- As each group finishes assembling their columns, have them tape each column to a corner of the cardboard base. Students can then go back to their activity books and make a prediction about the amount of weight each type of column will hold. [Tip: Pass around a few 1 pound books so that students can get a sense for how heavy they feel.]

For this activity form 7 groups of 4-5 students. I you have a group with 5 children, have the students in the group select the best 4 columns to be tested.

✪ Background ✪

The scientific inquiry process requires the experiment to test each structure under the exact same conditions.

✪ Teacher Tip ✪

Each group gets the same materials so that each experiment takes place under the same constraints. Distribute the tape in approximately equal pieces (about 1" in length), placing them on the edge of the table while students are writing their predictions.

Primary Activity: Column Quest (cont.)

- Testing procedures:
  - Each group will test (using books) the strength of each column structure.
  - Students will record the total amount of weight placed on each structure.
  - Students should watch for signs of failure: (e.g., buckling of the columns, crushing of the columns, or swaying of the structure)
- Observation:
  - Briefly explain that a column can fail in two ways, crushing or buckling. Crushing occurs when the maximum strength of the material has been reached. Buckling occurs before the column has achieved the limiting strength of the material, and thus occurs under fewer loads than crushing.
- Continue loading until the structure collapses. The total load capacity of the structure is the total number of ounces/pounds on the structure, not including the one that caused the collapse. Record the results on the *Column Quest!* poster and have students copy the results into their worksheets.
  - As each group tests their structure, incorporate discussions that draw attention to *how* the columns collapse, and where the failures are (e.g., failure does not usually happen where the column has been reinforced with tape).
- Have students compare the results of the experiment to their original predictions. *Who predicted that the circle would be the strongest?*
- Encourage students to share why the circle was the strongest shape. Ask guiding questions such as: *What is special about the circle? What makes it different from all the other shapes we tested?*

Basic explanation:
A column is only as strong as its weakest point. Columns with triangle, square, and pentagon shapes have several points of weakness – at the folds. Cylinders don't have any folds, so they don't have any points of weakness and can spread the load they're bearing out evenly.

Extended explanation:
Columns with circular cross-sections are strongest (for a given height and amount of material) because the material is the most evenly distributed around the perimeter and is the furthest away from the vertical axis. In a square, the corners are the only points that are far away from the axis, but more of the total material is actually closer to the axis than in a circle. [see inset]

15 min. **Wrap-Up**

- *Why is the circular column the strongest column?* Have a brief discussion: *Does the height of a column have any bearing on its ability to hold more weight?*

✪ Teacher Tip ✪

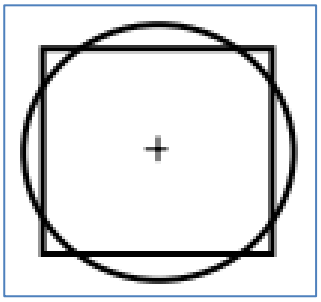
If the structure still stands after all available books have been used, you can begin adding other available items. Just remember to weigh them on the food scale prior to adding them to the bin or top of the platform.

✪ Extension ✪

Ask students if they can name other factors that might affect column strength (e.g., width, type of materials used, reinforcements applied, carefulness of construction, etc.).

✪ Background ✪

Two columns, one hollow and one solid, made up of the same amount of material will have different strengths. The hollow column will be stronger, for a given amount of material and column height, than the solid column, because all of the material in it is as far from the axis as possible.



The more material is spread out, the stronger the column.

Lesson 2 Vocabulary

structural grid	a skeleton framework designed to support a building; a structure composed of columns and beams connected to one another
beam	a horizontal, rigid structural member designed to carry and transfer loads
column	a vertical, rigid, upright structural member designed to carry loads
load	any forces that act upon a structure; weight
live load	any movable load on a structure including people, furniture, snow, rain water, and any movable equipment
dead load	the actual weight of the structure and the permanent fixtures and equipment (e.g., the walls, the floor, the ceiling); dead load is static

Lesson 2	Standards Addressed

Core State Standards (CCSS)-Mathematics

CCSS.Math.Content.4.MD.A.1

Know relative sizes of measurement units within one system of units including km, m, cm; kg, g; lb, oz.; l, ml; hr, min, sec. Within a single system of measurement, express measurements in a larger unit in terms of a smaller unit.

Next Generation Science Standard (NGSS)

3-5 ETS1 Engineering Design

3-5-ETS1-3 Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Blueprint for Teaching & Learning in the Arts

Art Making (Grade 5)

Sculpture: create a sculpture that demonstrates stable construction of a three dimensional form

Lesson 2	Standards Addressed

Common Core State Standards (CCSS)-Mathematics

7.SP.C.6 Approximate the probability of a chance event by collecting data on the chance process that produces it and observing its long-run relative frequency, and predict the approximate relative frequency given the probability.

Next Generation Science Standard (NGSS)

MS-ETS1-3 Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4. Develop a model to generate data for interactive testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Column Quest

Skyscrapers- After-school

Brainstorming!

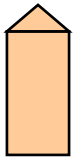
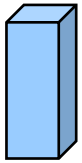
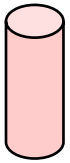
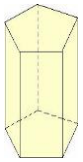
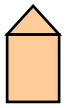
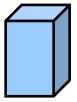
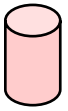
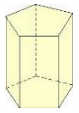
Which of the column shapes below will be able to hold the most weight and why? (select only one)

Triangle ☐ Tall ☐ Short _____

Square ☐ Tall ☐ Short _____

Circle ☐ Tall ☐ Short _____

Pentagon ☐ Tall ☐ Short _____

	Tall Triangle	Tall Square	Tall Circle	Tall Pentagon	Short Triangle	Short Square	Short Circle	Short Pentagon
								
Predict: How many 2lb weights will it hold?								
Live Load: How many weights did it hold before collapsing?								
Conclusion: Which shape and size is the strongest?	The _____was the strongest column shape because it held _____ weights.							