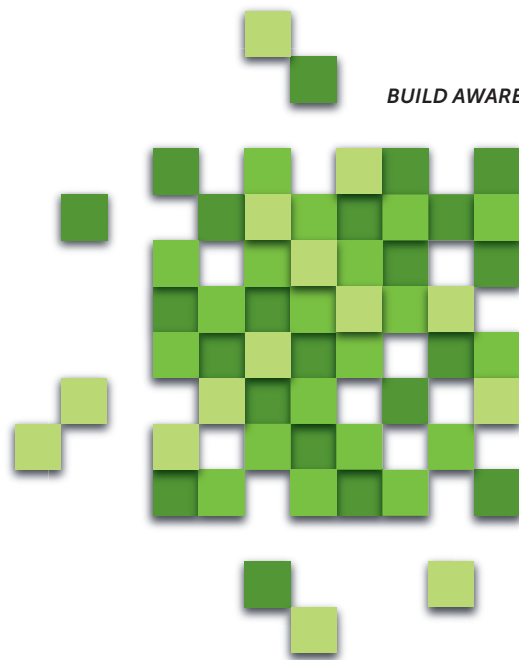


# BRIDGE BREAK

2017 EDUCATOR AND VOLUNTEER RESOURCE GUIDE



*BUILD AWARENESS. BUILD KNOWLEDGE. BUILD COMMUNITY.*

DESIGN  
LAB

LEARN AND BUILD

**AFC** ARCHITECTURAL  
FOUNDATION  
OF CINCINNATI

[www.architecturecincy.org](http://www.architecturecincy.org)

 **AIA Cincinnati**  
A Chapter of The American Institute of Architects



# WELCOME

## DESIGN LAB MISSION

The Architectural Foundation of Cincinnati, in association with AIA Cincinnati, offers **DESIGN LAB** to community schools to broaden and deepen student awareness and understanding of our built environment.

We do this by:

- Creating thematic annual educational programs aligned with state learning standards, implemented through an active partnership between educators and professionals in the built environment.
- Offering appropriate grade level content, lesson plans and learning goals.
- Providing educators with a useful and imaginative tool to help meet educational goals in a variety of academic and enrichment subject areas.

## DEAR EDUCATORS AND VOLUNTEERS,

Welcome to **Design LAB: Learn And Build!** The Architectural Foundation of Cincinnati, in association with AIA Cincinnati, is pleased to offer this hands-on, project-based learning experience to our community's schools and students. With the generous gift of your time and talent, over 100 classrooms and 1,900 students will be able to participate in this creative and unique educational program for 2016.

For over 20 years, **Design LAB: Learn And Build** (formerly ABC) has aimed to assist K-12 students in learning about how they can plan, communicate and thoughtfully build their environments. As students design and model their projects, they also build an awareness, knowledge and confidence about themselves, their ideas and how they might like to engage as citizens of the world.

As always, we welcome your input, insights and suggestions about how to improve and strengthen **Design LAB** in partnership with you, the educational and professional communities. With your support and a multidisciplinary curriculum, students will gain an appreciation of their built environment, and the interactive role they can have in shaping it. Please feel free to contact us anytime with your comments and questions. **Thank you for your participation!**

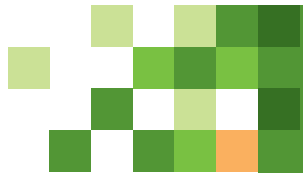


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# IMPORTANT INFORMATION FOR EDUCATORS

**THANK YOU FOR PARTICIPATING IN DESIGN LAB!** We hope that this experience will be a great one for you and your classroom. This page contains some tips and information to make sure that it is the awesome experience that it should be.

**TAKE FULL ADVANTAGE OF THE TIME YOU HAVE WITH YOUR VOLUNTEER IN THE CLASSROOM.** They have a depth of knowledge and exposure to the built environment that can bring this program to life in the classroom. However, these volunteers do have a career and likely cannot be in your classroom each time you work on Design LAB. They are also not educators and for some, this may be their first foray into a classroom environment.

**MAKE YOUR GOALS AND EXPECTATIONS FOR YOUR CLASSROOM'S PARTICIPATION IN DESIGN LAB CLEAR TO BOTH THE STUDENTS AND VOLUNTEERS.** This project is yours to direct and your volunteer is an assistant and a knowledge resource. They also give students a look into a potential career path, one of the many perks of this program. Be sure to ask them about their profession (or program in school, for our wonderful student volunteers) and allow them to talk to the students about what their days look like and about real-world challenges/solutions.

**MAINTAIN GREAT COMMUNICATION WITH YOUR VOLUNTEER.** Collaborate on a plan for the program and remain flexible. You will likely need to make adjustments, but going in with a plan is a pro move. Support your volunteer with any unfamiliar classroom circumstances and lead the process to implement the best ways of reaching achievement goals for your students.



**LESSON PLANS AND ACTIVITIES** This guide contains foundational education about the built environment, instructions on how to implement a constructive and fun critique/presentation, as well as suggested activities pertaining to the annual challenge. The initial presentations and activities are necessary for a successful program and we do highly encourage the critiques/presentations as part of the learning process. However, **the entirety of this guide is yours to use as a resource**, do not feel like you have to use every page. **Pick what works best for your class and your students** and feel free to add your own activities or lessons as you see fit.

**LEARNING OUTCOMES** We ask educators to conduct a pre and post assessment with their students and return them to our office (electronically or by mail). The data we collect from these helps us improve the program and support fundraising efforts. While our program is extremely versatile, there are key learning components that will be covered in the initial presentations and these cover a foundational understanding of the built environment.

The learning that occurs during this program that we can test for is limited. The growth that occurs is usually based around teamwork, creativity, confidence, and an array of other great outcomes that cannot be tested, but are applicable in the real world. What we are testing for are foundational aspects that are very important to modeling and building. Do let your students discover through tinkering and fumbling through their model builds. **This program is truly about the process, try not to focus on the end result.**

**ABOVE ALL, HAVE FUN!** Students can become frustrated as they build their models. Laugh and learn from failures and highlight the growth that occurs from rebuilding. That is what the built environment is all about!

If you have any questions or need assistance during the program for any reason, please contact us at [EdDir@architecturecincy.org](mailto:EdDir@architecturecincy.org) or 513.421.4469. We want to know how the program is going in your classroom and if there is anything we can do to help.





# IMPORTANT INFORMATION FOR VOLUNTEERS

## THANK YOU FOR PARTICIPATING IN DESIGN LAB!

We want to make sure that you go into this program prepared so that it is a great experience for you, your educator, and your students. Please read this page carefully, as it will provide information and advice that will help you make the most of your time with Design LAB.

## THE CULTURE OF CLASSROOMS WILL VARY BASED ON THE SCHOOL TYPES AND LOCATIONS.

Talk your teacher to understand the classroom dynamics and to understand the best way to communicate with the students. Keep in mind that the more challenging the classroom, the more you and the students will gain from the experience. Remember to be patient with your students. The model build can be frustrating for some and with students having different levels of exposure to the information that is presented to them, some of them may find it difficult. Each student will benefit from your willingness to share your passion and creativity, even if it does not always seem that way. It is not essential for a third grader to completely understand scale, it is essential that they use their creativity and have fun while taking a closer look at the built environment.

**TIMING.** You are an extremely valuable resource for the classroom, but your time there is limited. Your creativity, expertise, and passion is all of great use to your classroom; so be mindful of effective ways to leverage the time you have available to your students.



**STAY FLEXIBLE WHEN PLANS CHANGE.** Things don't always go per the plan, especially when it comes to building models. If there are any differences in visions or goals for the classroom, this is something you should speak to your educator about.

**LEARN FROM YOUR STUDENTS.** Don't look at this as a one-sided relationship. You can gain just as much from this experience as the students can, be open to it. Acknowledge their innovative thinking and lack of inhibition, realize how keyed in they are to the problems facing their communities and the creative responses they have for solutions. Understand how much they have to offer the world and treat them accordingly.

**ABOVE ALL, HAVE FUN!** Don't get caught up if students are having a hard time grasping certain aspects of this project. If you are having fun, they will likely be having fun as well and the learning will occur naturally throughout the course of the program. Laugh through the "trying" phase with them. Encourage them to keep going. Sharing your enthusiasm is contagious and will inspire students to express theirs as well. Design LAB is possibly their first in-depth exposure to built environment concepts, and it has proven potential to elevate career aspirations.

If your students are bringing their projects to Cincinnati's Public Library exhibit at the end of the program or entering into the Bridge Break Competition, try to make it there to **celebrate with them**. You were part of the team, too!

If you have any questions or need assistance during the program for any reason, please contact us at [EdDir@architecturecincy.org](mailto:EdDir@architecturecincy.org) or 513.421.4469. We want to know how the program is going in your classroom and if there is anything we can do to help.



# ACKNOWLEDGEMENTS

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Design LAB is only possible thanks to the generous, energetic and thoughtful work of **all participating educators and classroom volunteers**. Your work in the classroom with students broadens their horizons and hones their skills in important ways no textbook ever could.

We also thank our sponsors and program volunteers, who contribute the treasure and time needed to implement Design LAB.

## 2016-17 DESIGN LAB ADVISORY BOARD

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# PROGRAM OVERVIEW





# CALENDAR

IN-CLASS WORK TIME

## DECEMBER 2016 | TEAMS ASSIGNED & FIRST CLASSROOM VISIT

Educators and classroom volunteers will receive an e-mail with their assignment information. You are responsible for coordinating the date and time for initial presentations and return visits. Plan a first classroom visit in the first two weeks of December, prior to holiday break. See **"FIRST CLASSROOM VISIT"** and **drawing activity for suggestions.**

## JANUARY 3, 2017 | PROJECT KICK-OFF

The classroom PowerPoint and all Program Materials will be posted on Dropbox and on the AFC website. All participating educators and classroom volunteers will receive an electronic invitation to access program materials. If you do not receive an invitation, email [eddir@architecturecincy.org](mailto:eddir@architecturecincy.org)

## JANUARY 3 - APRIL 28, 2017 | RESEARCH, DESIGN & CREATION PERIOD

See the Design Challenge and **week-by-week** timeline for a breakdown of suggested benchmarks and order of activities for the completion of projects.

## SATURDAY, APRIL 29, 2017 | DESIGN LAB EXHIBIT: MODEL DROP OFF

Time: 9:00am-12:00pm

Location: Public Library Of Cincinnati & Hamilton County, Main Branch 800 Vine St., Cincinnati 45202

See **DESIGN FAIR EXHIBITION & REQUIREMENTS** for **directions and drop-off details.**

## APRIL 30, 2017 | BRIDGE BREAK

Time: TBD

Location: TBD

Students who are participating in **BRIDGE BREAK** can bring their bridge models to our **BRIDGE BREAK** competition to see how their bridges weigh against their components when tested for strength.

## APRIL 29 – MAY 6, 2017 | DESIGN LAB EXHIBIT WEEK

Time: During normal Library hours, [www.cincinnati.library.org/info/hours.asp](http://www.cincinnati.library.org/info/hours.asp)

Location: Public Library Of Cincinnati & Hamilton County, Main Branch 800 Vine St., Cincinnati 45202

Social Media Exhibit will be up on Design LAB's Facebook. Vote for your favorite project by "Liking" it by May 4th.

## MAY 2, 2017 | DESIGN FAIR JURY REVIEW

See the **DESIGN FAIR EXHIBITION & COMPETITION REQUIREMENTS** for **jury award categories.**

## MAY 6, 2017 | DESIGN LAB CLOSING RECEPTION & PROJECT PICK-UP

See the **DESIGN FAIR EXHIBITION & COMPETITION REQUIREMENTS** for **jury award categories.**

Location: Public Library Of Cincinnati & Hamilton County, Main Branch 800 Vine St., Cincinnati 45202

Time: 10:00 am-1:00 pm

- 10:00 am-12:00pm Students Present & Discuss Their Work / Last Chance to View Exhibit
- 12:00 pm-1:00 pm DESIGN LAB Fair Awards Presentation
- 1:00 pm -2:00 pm Project Pick-Up / Removal
- 10:00 am-2:00 pm **PROJECT CHECK-OUT & Certificates Pick-up**  
**Educators or assigned classroom parent to pick up certificates for your class.**

**PLEASE NOTE: ALL PROJECTS MUST BE SIGNED OUT FROM MAIN LIBRARY EXHIBITION SPACE NO LATER THAN 2:00pm SATURDAY, MAY 7th. PROJECTS REMAINING AFTER 2:00pm WILL BE DISCARDED.**

PRESENTATION SCHEDULE



## JUNE 2017 | EDUCATOR & VOLUNTEER APPRECIATION PARTY

Details Forthcoming



# PROJECT TIMELINE

## SUGGESTED WEEK-BY-WEEK TIMELINE

The following schedule is based on a classroom working on the project for one 45–60 minute class period per week. You may choose for students to participate more frequently and distribute information, activities and worksheets for review/completion outside of class. Other than assessments, this outline schedule is not mandatory, and is intended to help guide your class through the design process. Adjust at your discretion and include holidays, Spring Break and possible snow days in your overall Work Plan. Remind students to keep a folder with information and images to prepare their tri-fold project display. *Thank you!*

	MONTH/WEEK	PROJECT PHASE	SUGGESTED ACTIVITIES	
	<b>DECEMBER</b>	Intro Visit   Getting Acquainted	Activity, Materials Reminder, Pre-Assessments	
<b>CONCEPTS</b>	<b>JANUARY</b>			
	Week 1	DISCOVER	Project Introduction	Intro Presentation, Q&A
	Week 2	DISCOVER	Client & Site Phase	Client & Site Presentation, Selections
	Week 3	INTERPRET	Design Concepts & Inspiration	Structures & Spatial Awareness
	Week 4	INTERPRET	Understanding Sustainability	Sustainability and LEED Presentation
<b>DRAWINGS</b>	<b>FEBRUARY</b>			
	Week 5	IDEATE	Design Planning	Drawing to Scale
	Week 6	IDEATE	Design Planning	Plan, Section, & Elevation
	Week 7	EXPERIMENT	Design Planning	Develop Plans
	Week 8	EVALUATE	Presentations	Student Presentations & Critiques
<b>MODELS</b>	<b>MARCH</b>			
	Week 9	BUILD	Work Week	Begin Build of Testable Models
	Week 10	BUILD	Work Week	Build Testable Models
	Week 11	BUILD	Work Week	Build Testable Models
	Week 12	EVALUATE	Work Week	In-Class Bridge Break + Evaluation
	<b>APRIL</b>			
	Week 13	REBUILD	Work Week	Rebuild (modify designs based on results)
	Week 14	REBUILD	Work Week	Rebuild
	Week 15	REBUILD	Work Week	Rebuild
	Week 16	FINALIZE	Work Week	Finalize Rebuild

## OVERVIEW & PROJECT REQUIREMENTS

**In order to compete in the Bridge Break Competition, all rules must be followed. Any bridge that does not satisfy each requirement will be disqualified.**

### RULES OF THE ROAD

Projects may be developed in teams or individually. We recommend teams of four students. This limit ensures that each student will have ample opportunity to contribute to the design process, drawing, and model-building.

1. Models should offer real-world solutions to the design challenge. Embrace innovation and build a BRIDGE that could actually be built to address a real-world problem we are facing today.
2. You are limited to the materials you can use. You may only use balsa wood, wood glue, and 100% cotton string.
3. The total mass of the bridge must not exceed 100.0 grams (g).
4. The bridge shall contain no element wider than 1.0 cm (3/0") nor thicker than 0.65 cm (1/4"). Two or more elements, each separately meeting this requirement, may be laminated together to construct members exceeding these dimensions.
5. The bridge shall allow a 5.0 cm cube to pass underneath without touching the structure. The bridge shall also allow a 40.0 cm long by 2.0 cm high board to slide underneath (sideways) without touching the structure.
6. The bridge shall be "free standing".
7. An approximately level, smooth roadway surface, of minimum length 40.0 cm and above the 5.0 cm mark, shall be provided, across which a small metal car (e.g. Matchbox, Hot Wheels) will roll when given a single, light push of the hand. This roadway shall have a minimum width of 5.0 cm and shall allow a 5.0 cm cube to pass freely along its extent. Note: the roadway materials must conform to rule #3.
8. No fastening mechanism except mechanical interlock of the balsa pieces or commercial glue is permitted. If string is employed (in the case of suspension or cable-stay designs), it may only serve as it's own connection, and not be a part of connections between balsa members.
9. The bridge design shall allow the 'standard test frame' to be placed on the roadway surface with the load support rod(s) extending beyond the bridge sides.

**HAVE EACH TEAM KEEP A FOLDER** containing the Design Ideas Form(s) and all additional research, sketches, concept images, photographs, etc. for the project, and use to prepare the tri-fold panel.



### TAKE PHOTOS!

Please take photos and send them to us.

We love to see what the students are up to and use photos to show off the students' work. If there are students whose photos we cannot show publicly, just let us know and we will ensure they are not made public. We love to post photos on social media and use them for marketing as well as fundraising for the program.



# BRIDGE BREAK CONTEST FORM

School: \_\_\_\_\_

# \_\_\_\_\_

Teacher: \_\_\_\_\_

Student(s): \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

**1. ALLOWABLE MATERIALS** \_\_\_\_\_ / 5 points

- Commercially available rectangular balsa stock
- Wood glue
- 100% cotton string

**2. MAXIMUM MASS** *EQUAL OR LESS THAN 100.0 grams* \_\_\_\_\_ / 5 points

**BRIDGE WEIGHT**

**3. COMPONENT SIZE** \_\_\_\_\_ / 5 points

- NO WIDER THAN 1.0 cm
- NO THICKER THAN .65 cm (1/4")

**4. SPAN AND CLEARANCE** \_\_\_\_\_ / 5 points

- 5.0 cm x 5.0 cm at CENTER
- 40.0 cm x 2.0 cm high board can slide underneath (sideways) without touching the structure.

**5. FREE STANDING** \_\_\_\_\_ / 5 points

**6. SMOOTH ROADWAY** \_\_\_\_\_ / 10 points

- Minimum length 40.0 cm
- Above the 5.0 cm mark (CLEARANCE ABOVE)
- Matchbox car can roll when given a single, light push of the hand
- Minimum width = 5.0 cm
- Allow a 5.0 cm cube to pass freely along its extent
- Note: the roadway materials must conform to rule #3.

**7. FASTENING** \_\_\_\_\_ / 5 points

- GLUE ONLY
- String attaches string only and does not provide additional strength to wood connections.

**8. FITS STANDARD TEST FRAME & LOAD SUPPORTS** \_\_\_\_\_ / 10 points

**WEIGHT HELD:** \_\_\_\_\_ LB(S) \_\_\_\_\_ OZ

RATIO: \_\_\_\_\_





# FIRST CLASSROOM VISIT

## GETTING ACQUAINTED

Prior to the first visit with the class, we strongly recommend that educators and volunteers schedule a meeting without the students. We recommend having this in the classroom, outside of classroom hours, so the volunteer knows where to go and has seen the classroom before the program begins. We recommend doing this some time in December, before the first official classroom visit.

It is recommended that educators and volunteers schedule an introductory classroom visit in December prior to the students' winter holiday. Volunteers, spend time during your first visit introducing yourself and getting to know the students you'll be working with.

Consider questions, discussions, and activities to get students thinking critically about the built environment. Some students have never really stopped to consider what goes into creating the environments and spaces that they occupy every day. Spend a few minutes helping them to think critically about ideas such as:

- The factors that are important in the design of a new structure or space.
- Which systems make up a building and what they are designed to do (this is a great place to make a comparison to the body – the building envelope is the shell, the structure is the skeleton, HVAC is the respiratory system, etc.)
- Spaces they like or don't like in buildings (e.g. their school), and why.

## DESIGN THINKING ACTIVITY

The first official classroom visit is meant to introduce the volunteer to the classroom and get students excited about the program. This activity is meant to do just that! If both parts of this are not possible for your classroom, elaborate on the brainstorming or try to have them sketch different versions of bridges.

### **BRAINSTORMING**

**DURATION:** 5 - 10 Minutes

**ACTIVITY:** Ask students what they think of when they think of "BRIDGE" and write it on the board. If they don't start thinking past our common ideas of what a bridge are, push them to think more abstractly or about how bridges can be used to help animals or for walking, etc. Bring up the different uses of the word bridge: used in music, card games, etc.



# BRIDGE BREAK INTRODUCTION ACTIVITY

## BRIDGE BREAK

**DURATION:** 40 - 50 Minutes

**MATERIALS NEEDED:**

EACH GROUP:

- (15) Uncooked spaghetti
- (25) Medium & small sized marshmallows
- Measuring stick or ruler

ENTIRE CLASS CAN SHARE:

- Small paper cup
- 200-300 pennies (for weights)
- Two desks placed 10" apart to support each side of bridges

**INSTRUCTIONS:**

1. Use your discretion to decide how many students you want in each group (2-4 is suggested).
2. Pass out marshmallows and spaghetti to each group. Let them know they are working as groups of engineers to build the strongest bridge ever made from spaghetti.
3. Their bridge must span the "river" between the desks, which is 10 inches. If their bridge is only 10 inches in length, will it work? Let them figure out how long it needs to be.
4. The rules are that they can only use spaghetti & marshmallows to try to build the strongest bridge.
5. To test the strength of their final bridge, you can place the cup on top of the bridge and add pennies. How many pennies does it take to break it? Whose bridge can withstand the most pennies?
6. If your volunteer has the ability to address ways in which each bridge could have been improved, have them talk about that as each group's bridge breaks.
7. Congratulate your students on the successful completion of a Bridge Break! Ensure them that they will have better understanding of this before they embark on their model building.

\*NOTE: the students will probably have no idea what they are doing and that is kind of the point. They will be learning this stuff during the program! So allow them to fumble around, it is just to get them thinking about how bridges are actually made and get them excited to build one after they have some foundational knowledge of how to do so (and maybe even encourage them to pay attention during those classes).

OPTIONAL ADDITIONS: Have one wall of the room assigned "triangles" and the other side assigned "squares". Ask students which they think is more stable, triangles or squares, and have them go to the wall they believe is correct. They can only make these shapes to create their bridge.

Have the students make predictions about how many pennies their bridge can hold before testing them.

For older grades, try to push them by placing the desks 20 inches apart.

# INTRODUCTION TO DESIGN LAB: BRIDGE

## LEARNING OUTCOMES:

- Students will more fully understand what Design LAB is and what they will be doing during the course of the program. They will be given a chance to ask questions if they are unsure of anything.
- Students will have a better understanding of different types of bridges and how they impact the world around them.

## MATERIALS NEEDED:

- Digital Presentation 1
- Notebooks
- Pencils

This lesson is meant to give students a cohesive understanding of what they will be doing throughout the program. If they haven't completed their pre-test yet, they must do that before going any further with this lesson.

Present the introductory information found in the Powerpoint which is located at [www.architecturecincy.org/programs/design-lab/edu-res/](http://www.architecturecincy.org/programs/design-lab/edu-res/)

If time allows at the end of the lesson, students will be instructed at the end of the Powerpoint to journal how they are feeling about the project ahead and any initial ideas they have for it. Feel free to have this as an open class discussion or a personal reflection time.

## VOCABULARY

**Bridge** - a structure carrying a pathway or roadway over a depression or obstacle; a time, place, or means of connection or transition

**Built Environment** - the man-made surroundings that provide the setting for human activity, ranging in scale from buildings and parks or green space to neighborhoods and cities that can often include their supporting infrastructure, such as water supply or energy networks

**Design Process** - an approach for breaking down a large project into manageable chunks.

Architects, engineers, scientists, and other thinkers use the design process to solve a variety of problems.

**Compression** - Objects get pressed/crushed

**Tension** - Objects get pulled

# BODY BUILDING TO UNDERSTAND BRIDGE TYPES

## LEARNING OUTCOMES:

- Students will understand how different bridge types withhold loads
- Students will act out the bridge types with assigned loads.

## MATERIALS NEEDED

- Notebooks
- Space for Movement
- Digital Presentation 2

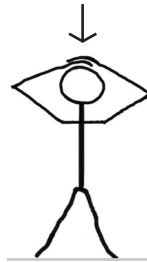
This lesson will be a fun one that gets students out of their seats to better understand different kinds of bridges. You can go through all of the types of bridges and then do the "Body Building" exercises, or go along with the guide and do the exercises as you talk about each bridge type.

Each page following this one will describe a separate bridge type and guide you through the "Body Building" activity. To begin, review tension and compression from Week 1.

### COMPRESSION

Have all the students stand up. Have them place their hands on their heads with your fingers interlaced. Ask them to push down.

Ask, "How does your neck feel? Squished together?" Tell them, "This is compression; the force that an arch or a column or a tower of a suspension bridge experiences." Then ask, "Can you feel the same squished forces in your back or in your legs? When do your legs feel this way, when you lift heavy objects? Have the students offer their own answers. Share when you feel compression.



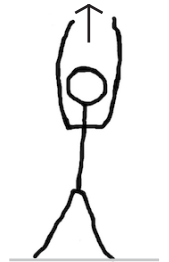
### TENSION

Still standing, with hands still on heads, pushing down, ask students, "Does any part of you feel stretched out?" Their arms, fingers or wrists might feel a stretching force. Tell the class, "Stretching is a tension force."

Now ask them to stretch straight upwards by reaching for the ceiling. Ask them, "Do you feel stretching forces in your arms, back and legs?"

Have students pair up, stand to face each other at arms length, hold both hands and pull back gently. Their arms will be in tension. Ask if they can feel it. Now ask them to slowly increase the pull. Ask if they feel more of their body working. More force makes the body work harder.

Have the class all stand up. Ask them to bend over and touch their toes. Ask, "What part of you is stretched?" They should feel the tension, a stretch, all around the back part of the body (heels, calves, back and even shoulders).



## VOCABULARY

**Arch Bridge:** a bridge with abutments (the point where two structures or objects meet) at each end shaped as a curved arch. They work by transferring the weight of the bridge and its loads partially into a horizontal thrust by the abutment at either side.

**Suspension Bridge:** the deck (the load-bearing portion) is hung below suspension cables, ropes, or chains on vertical suspenders.

**Beam Bridge:** bridge span is supported by an abutment or pier at each end.

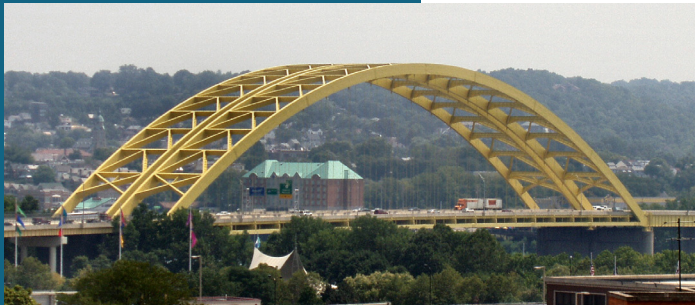
**Truss Bridge:** a type of bridge whose main element is a truss which is a structure of connected elements that form triangular units.

**Cable-Stayed Bridge:** has one or more towers (or pylons), from which cables support the bridge deck. A distinctive feature are the cables which run directly from the tower to the deck, normally forming a fan-like pattern or a series of parallel lines.

# ARCH BRIDGE

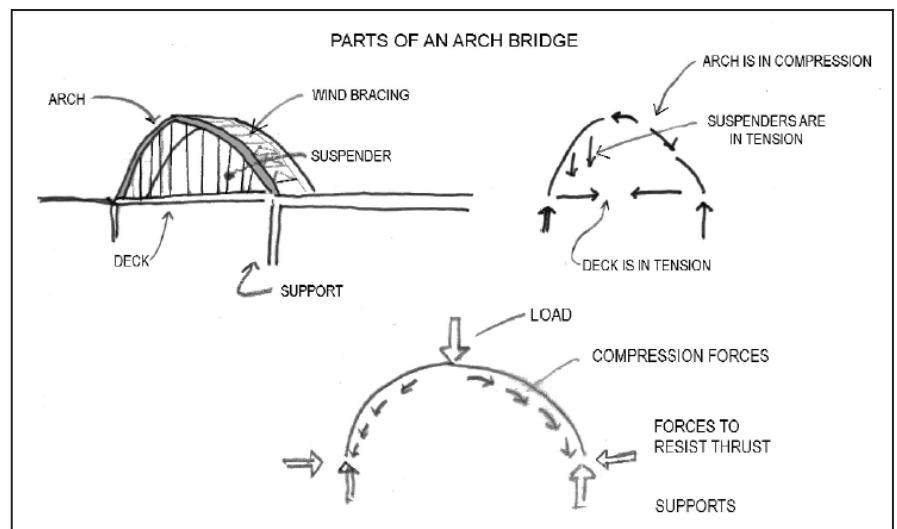
## BACKGROUND

Ancient arches were made of stone. Arches work by putting the material into compression. Stone (as well as steel and concrete) work well in compression. A material is in compression when its particles are being pushed together. A column holding up a building is a long thin compression element.



A modern example is the Daniel Carter Beard Bridge ("Big Mac") in Cincinnati. In the roman bridge the weight that the arch carries comes from the stones on top of the arch. In the DCB bridge the weight starts at the road deck, runs up through the vertical cables (tension) and is distributed into the arch.

The compression forces in an arch have to press ultimately against the ground. To receive those large forces, large abutments have to be created.



Arches are often heavy. They can carry more load by getting deeper. With its full length in compression, the material can buckle. One way of overcoming buckling is to use more material, and make the arch heavier. At some point too much of its strength is used to support just its own weight and too little strength is left to carry the superimposed loads of traffic.

# ARCH BRIDGE EXPERIMENT #1

*You will need a partner to do this experiment.*

## STEP 1:

The first person (Arch) places their elbows on a table, and clasps their hands together. The second person (Load) pushes straight down on top of Arch's hands.

The arms and hands form an ARCH.

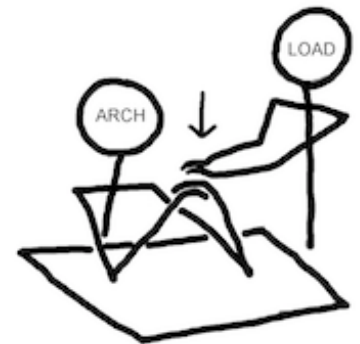


## STEP 2:

"Load" pushes on "Arch's" hands from the side.

Variation: Try to resist the downward force using only one hand, keeping it in its 'arch' position.

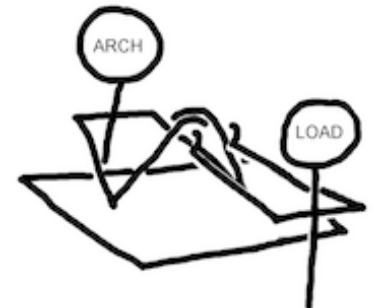
Can you hold more straight down force (load) with hands locked together or with just one hand alone? How much more? Twice the load?



## STEP 3:

Load pushes on the arch from the front, then pulls from the front.

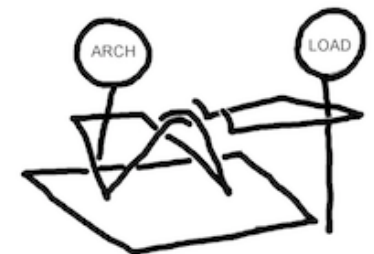
Is it easier to resist the pulling or the pushing?



## STEP 4:

Load pushes and pulls from the side.

Which side is in compression and which side is in tension when Load pushes or pulls?



**IN WHICH DIRECTION IS  
THE ARCH MOST STRONG?**





# ARCH BRIDGE EXPERIMENT #2

You will need a partner and two helpers to do this experiment.

## PART 1:

Stand with a friend facing each other about 5 feet apart (small children will need to be looser). Have someone help you each lean forward so that your hands may grab each other's shoulders.

Step back a little at a time, bending at the waist until your arms and legs are straight.

When you both feel your hands pushing against each other, you have made an arch that is holding part of your weight!

Can you feel the compression in your shoulders?

Do you feel your feet about to slide?



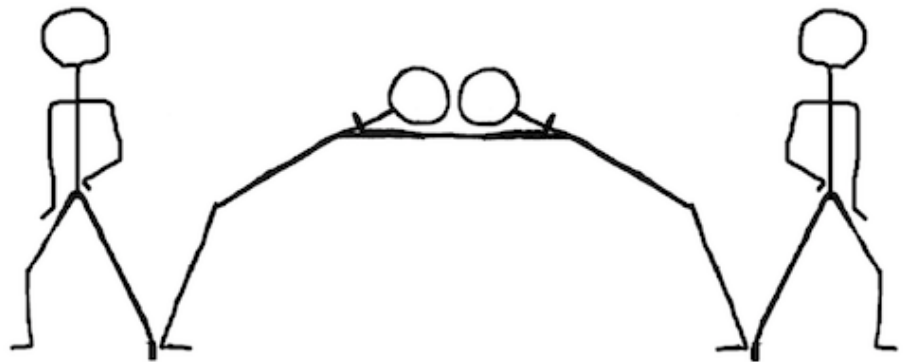
## PART 2:

If your 'assistants' brace their heels with their feet, they become buttresses, and you should be able to move your feet even further apart.

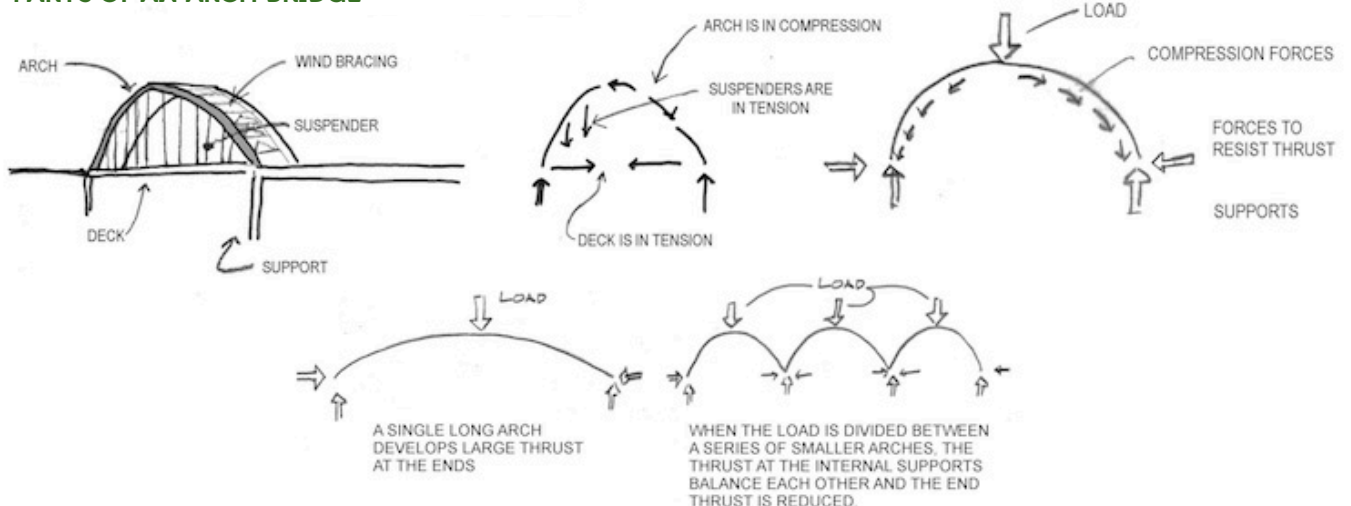
Can you spread your feet further apart? What happens to the curve of the arch when you do this?

**An arch is 100% in compression.**

Can you feel it?



## PARTS OF AN ARCH BRIDGE



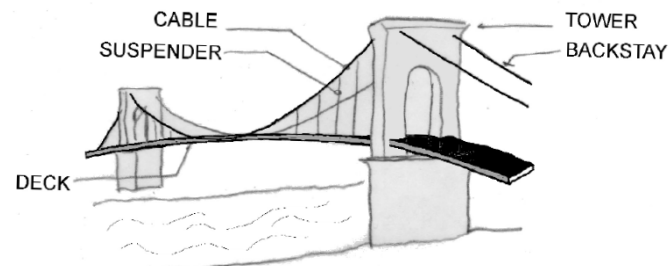


# SUSPENSION BRIDGE



Ancient suspension bridges were made of rope, vines or chains. Newer suspension bridges use steel plates or super-strong steel cables. Cables work by putting the material into tension. Stone and concrete do not work well in tension; they are too brittle and usually too heavy. A material is in tension when its particles are being pulled apart. A suspension bridge has a curved tension member.

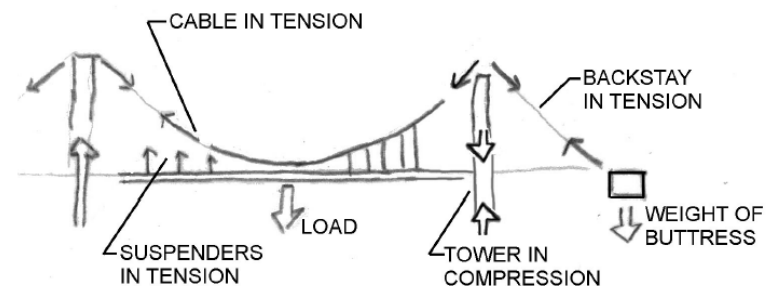
## PARTS OF A SUSPENSION BRIDGE:



Suspension bridges use a combination of tension and compression. The cables can only carry tension loads. By stretching across the towers, they pull down and create compression in the towers.

The cables that go from the top of the towers down to the ground are the backstays. The backstays are connected to huge rock or concrete piers buried in the ground. The backstays keep the towers from bending in.

## HOW A SUSPENSION BRIDGE WORKS:



Suspension bridges are very light. This allows them to span very long distances.



# SUSPENSION BRIDGE EXPERIMENT

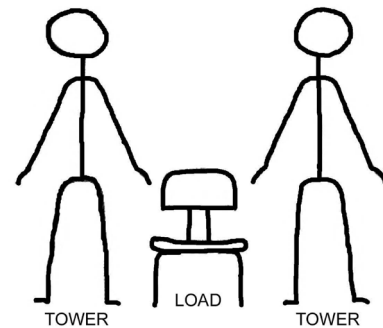
You will need 1 chair, 4 people and extra weights to do this experiment.

## STEP 1:

Two people stand on either side of a chair, facing the same direction. If someone were sitting in the chair, that person would also be facing the same direction.

The person on the right of the chair grabs the seat with their left hand, and the person on the left grabs the seat with their right hand.

The two people are the bridge towers, their arms holding the chair are the bridge cables, and the chair is the load, or bridge deck.



## STEP 2:

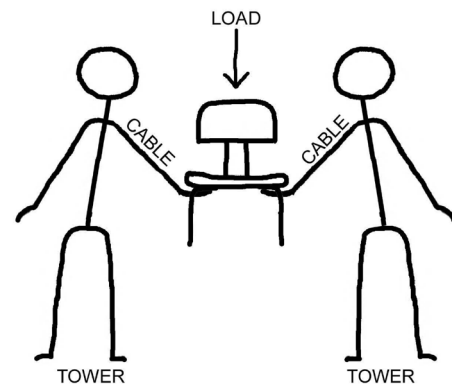
Lift the chair.

Do the two towers tend to lean in toward each other?

What happens if each person has their feet far apart?

Does this make it more or less stable?

What happens if they bring their feet close together?



## STEP 3:

Two people kneel or sit, one next to each tower, making a straight line.

The sitters then, reach up and take the free hands of the towers.

The sitters pull down gently until the towers are standing straight up.

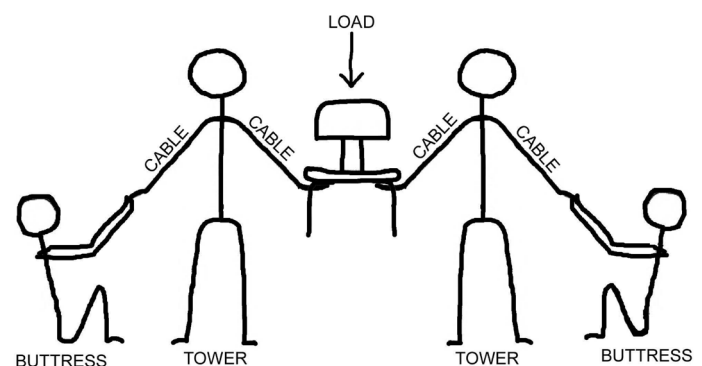
The sitters become the counterweights or BUTTRESSES for the towers.

How do the towers feel now?

Does each arm have the same amount of stretch in it?

What happens when you add weight to the chair?

The buttresses have to pull harder to keep the balance.



Who feels which forces?  
What parts are in COMPRESSION?  
What parts are in TENSION?

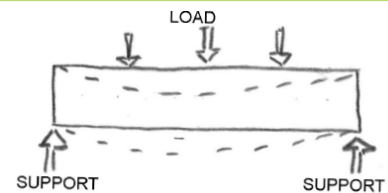
# BEAM BRIDGE



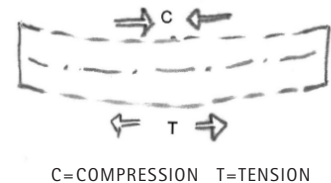
Ancient beam bridges were made primarily of wood. Modern beam-type bridges are made wood, iron, steel or concrete. How a beam operates is more complex than a cable or an arch. In the cable all of the material is in tension, but in a beam part of the material is in tension and part of the material is in compression.

## HOW A BEAM WORKS:

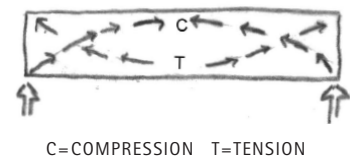
1. A beam supported at its ends and loaded in the middle deflects downward.



2. The top edge is in compression. The bottom edge is in tension. There is no stress in a line right through the middle.



3. The beam develops a compression arch across the top and a tension cable across the bottom.



The top of the beam has compression forces squeezing the material together, and the bottom of the beam has tension forces that stretch the material apart.

A beam needs to be made of material that can work well under both compression and tension forces. Wood is a good material for this. Stone is not a good material for a beam – it is strong in compression, but weak in tension. That's why it is good for arches but bad for beams. The same is true of concrete. To make a concrete beam, we need to add steel rods or cables at the bottom (in the tension area.) Long-span beams came into great use after 1850 when the production of large batches of steel became possible.

None of the big bridges crossing the Ohio River are beam-types because the span is too long and their weight would be too great. Beams are more often found in shorter spans such as those at many overpasses. Next time you are driving with your parents on the highway, look at the structure beneath the overpasses as you travel beneath them, and you will more often than not see steel wide-flange beams supported by concrete columns.

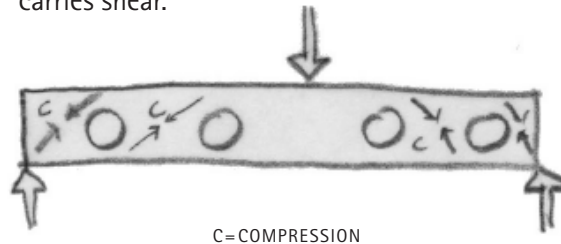
# TRUSS BRIDGE



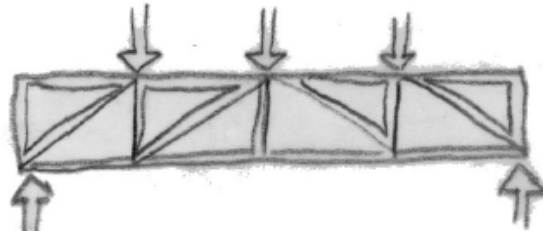
Trusses work much like beams: they carry a combination of compression and tension forces. The main difference is that trusses are less bulky (heavy) than beams. Beams use extra material in some areas; these areas don't use the full strength available to them. Engineers and builders can determine which portions of beams can be removed. The resulting truss concentrates the forces into many smaller members and eliminates the under-stressed areas of beams.

## HOW A TRUSS WORKS:

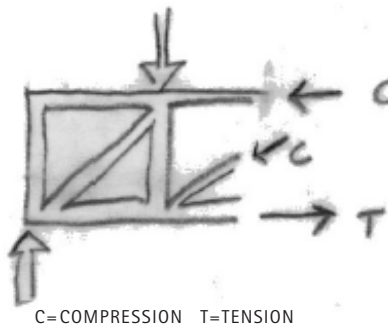
- 1) A castellated beam has a portion of the web removed, the remaining web carries shear.



- 2) A truss has vertical and diagonal struts to carry shear.



- 3) Like the beam, the truss has compression in the top chord, tension in the bottom chord, and either tension or compression in the vertical and diagonal components.





# TEST BEAM & TRUSS BRIDGES OUT!

Use some stiff paper to learn some of the properties of beams. Art paper that comes in a big tablet might work well.

**1) Take a stiff piece of paper 6 inches wide and 18 or 24 inches long.** If you lay it on two stacks of books so that each end is supported, you can make a thin beam with a 15 to 20 inch span. If you put even a slight load, like a small book, in the center, it will crumple and fail. Try putting another book on top of the paper at the supports. Does this keep it from sliding off as easily? Can you add more small books as a load? Record the number of books that cause it to fail. The beam fails in bending because it does not have enough depth. It is too thin.

**2) Now take the same sheet (or a similar one) and fold it accordion style.** Each fold should be 1 inch wide and 18 or 24 inches long. Now repeat the beam experiment. If the accordion just unfolds you can make two end plates 1 inch high and 2 inches long and glue the pleated ends of the beam to the end caps. After the glue has dried, load the beam. Does it carry a lot more load than the flat paper? How do you account for this? The beam doesn't use any more paper, it is just that pleating it makes it stiffer. Now your beam is 1 inch thick, not just a fraction of an inch.

**3) To make it stronger: make another pleated beam from a 6 inch by 18 inch sheet of paper the same as the first.** Cut two pieces of paper to be 2 inches by 18 inches. Lay one of the 2 x 18's on a table, apply glue to the ridges of the pleated sheet and stick it to the 2 x 18. After that glue has set, turn the assembly over and glue the other set of ridges to the other 2 x 18. Now you have a much stiffer beam. Load this new beam the same as the others, and chart the results.

**4) You can make a chart showing the relative stiffness of the three beams** by indicating the maximum load or number of books that the beam carries prior to collapsing.

**5) In the stiff beam with the paper top and bottom, these top and bottom sheets are the compression flanges of the beam.** The folded parts are the webs. In the beam without the top and bottom sheets the edges of the folded part carry compression and tension. There isn't much material there so they fail under a small load.

**6) Look carefully at the stiff beam with the paper top and bottom paper flanges as it fails.** What happens? Does the top paper crumple up? This is buckling. We would expect that the thin paper would buckle before the bottom paper would rip in tension. To improve the performance of the stiff beam, try gluing additional layers of paper to the top. Load the beam after each addition, plotting your results on your chart. Try to determine the optimal number. You can't improve the beam by adding more top sheets once the failure switches to tension rips on the bottom paper. Plot these results in your table.

**7) You could also determine which beam is the most efficient.** Add two more rows to your table. In one record the weight of each paper beam. (If you can't weigh them, count up how many 2 x 18 inch strips you used. Remember the initial pleated piece counts for 3 strips.) In the next row enter the ratio (or quotient) of the load (number of books) divided by the weight of the bridge (number of paper strips.) The highest ratio is the most efficient, it carries the most load for its own weight.



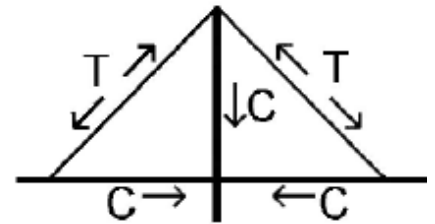
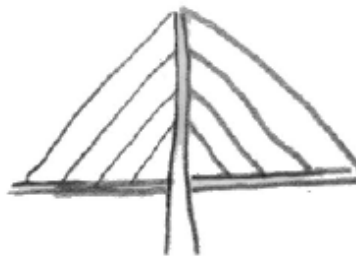
# CABLE-STAYED BRIDGE



The newest type of bridge to be developed is the cable-stayed bridge. They have gained great popularity in recent years because of their great beauty and economy. They cannot be used for truly large spans like a suspension bridge, but they are very good for the more moderate spans that trusses have been used for.

## FORCES IN A CABLE-STAYED BRIDGE

The cables are in tension and their towers and deck are in compression.



C= COMPRESSION T= TENSION

Though the cable-stayed bridges look a lot like a suspension bridges, their function is quite different. A cable-stayed bridge could be constructed using just one tower. It would be placed in the middle of the river as shown in the first diagram above. The weight of one side of the bridge would balance the weight of the other side. When two towers are used the cables do not run from one tower to the other. Instead they run from the tower to the road deck. Each side works independently.

Look at the photo below of the construction of the William H. Harsha Bridge. You will see that one tower and the roadway it supports are almost complete, while the cables and roadway of the other tower have not been started.





# BRIDGES SCAVENGER HUNT

- 1) What is the third longest suspension bridge in the world? \_\_\_\_\_  
Where is it located? \_\_\_\_\_  
How much shorter is it than the Akashi Kaikyo Bridge? \_\_\_\_\_
- 2) How long is the Confederation Bridge? \_\_\_\_\_  
List one interesting fact about this historic bridge: \_\_\_\_\_
- 3) Name the bridge located in Brunswick, Georgia: \_\_\_\_\_  
How long is this bridge? \_\_\_\_\_  
Who was given credit for asking this question? \_\_\_\_\_
- 4) Where is the Sunshine Skyway Bridge located? \_\_\_\_\_  
What was the cost of this bridge? \_\_\_\_\_  
What type of bridge is the Sunshine Skyway? \_\_\_\_\_
- 5) How many Brooklyn Bridges would it take to span the length of one Akashi Kaikyo Bridge? \_\_\_\_\_  
How long did it take to build this huge bridge? \_\_\_\_\_
- 6) When did construction begin and end on the Sydney Harbour Bridge? \_\_\_\_\_
- 7) How long and wide is the Stone Mountain Bridge? \_\_\_\_\_  
What type of truss is this bridge? \_\_\_\_\_
- 8) What body of water does the Peace Bridge cross? \_\_\_\_\_
- 9) Who designed the Golden Gate Bridge? \_\_\_\_\_  
When was it completed and opened to vehicle traffic? \_\_\_\_\_
- 10) Name three reasons you would want to build a cable-stayed bridge instead of a suspension bridge:  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_
- 11) What type of bridge is the Tower Bridge in London, England? \_\_\_\_\_  
How long did it take to build the bridge? \_\_\_\_\_  
In what year was it completed? \_\_\_\_\_



**LEARNING OUTCOMES**

- Students will know different types of structures and understand the forces that they are built to withstand.
- Students will understand how they relate to the space they occupy and how different structures and natural elements exist in a space.

**MATERIALS NEEDED**

- Digital Presentation 3
- Notebooks
- Pencils
- Open Space

This will be a lesson full of exploration. To do both of the lessons fully, you may need two class periods. If you do not have time to do both, pick a couple of items from each lesson. It is important to get the students out of their seat and actually FEELING how structures work with the different loads they are dealt. Feeling how compression and tension work will be important to help them understand how their bridges should be built.

**VOCABULARY**

**Structure** - parts or elements of a built object and how they are combined and organized to hold the object together and keep its shape

**Loads** - natural forces that work against structures (gravity, weight, movement, vibrations, weather events, movement of the earth)

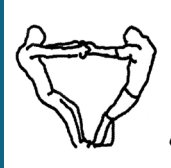
**Spatial** - how objects fit together in a space

# STRUCTURES

Basic structural elements are used in various combinations to make up the built environment. Look around your school, community or neighborhood and see which elements you can find and identify how the loads placed upon them are transferred to the **ground**.

The structural elements to the right visually describe each element and how it reacts to **gravity** loads placed upon it. Looking at these diagrams, try to act out the structural elements with your classmates and see what it feels like when different loads are placed upon you.

## TENSION:



A pulling, stretching, and expanding action

## COMPRESSION:



A pressing, pushing, squeezing, and compacting action

STRUCTURE	DEFINITION	EXAMPLE	LOAD	ACT IT OUT
<b>COLUMN</b>	A vertical linear element used to support a beam, floor, or roof			
<b>BEAM</b>	A horizontal linear element spanning across an opening, supported at both ends			
<b>WALL</b>	A vertical planar element that separates two spaces			
<b>SLAB</b>	A horizontal planar element that separates two spaces			
<b>CANTILEVER</b>	A horizontal structural element supported only at one end			
<b>FRAME</b>	A rectangular arrangement of linear structural elements			
<b>TRUSS</b>	A 2-dimensional triangular arrangement of linear structural elements			
<b>SPACEFRAME</b>	A 3-dimensional triangular arrangement of linear structural elements			
<b>ARCH</b>	A curving or pointed element that spans across an opening			
<b>VAULT</b>	A series of parallel curved or pointed arches			
<b>DOME</b>	A series of curved or pointed arches on a round or many-sided base			
<b>FOUNDATION</b>	Anchors a building by transferring the loads acting upon the building into the ground			

Source Credit: *Architecture In Education, The Foundation for Architecture, Philadelphia.*

# SUSTAINABILITY IN THE BUILT ENVIRONMENT

## LEARNING OUTCOMES

- Students will understand what sustainability means to the built environment and different ways to build a sustainable building.
- Students will learn about alternative ways in which the built environment can help the natural environment.

## MATERIALS NEEDED

- Digital Presentation 4
- Notebooks
- Pencils

This is one of the most important lessons, but there is also a lot of information to cover. Depending on the age and level of your students, some of it may seem daunting. Choose the sections that will relate and resonate with your students the best.

One fun way to go through this information is to do an "audit" on the school as you are going through each item. Grade your school on how it does in each of these categories. The accompanying powerpoint will also help bring some of these concepts to life for the students.

## VOCABULARY

**Sustainability** - ability to continue a defined behavior indefinitely

**Renewable** - relating to a natural resource, such as solar energy, water, or wood, that is never used up or that can be replaced by new growth indefinitely

**Organic** - of, relating to, or derived from living matter

**Pervious** - allowing water to pass through; permeable

**Solar Power** - power obtained by harnessing the energy of the sun's rays



# SUSTAINABILITY IN THE BUILT ENVIRONMENT

## INTRODUCTION TO SUSTAINABLE BUILDING

A "Green Structure" does not mean the structure is colored green. A "green" way of creating structures means that you respect and try to understand nature in every way that you can. It means that you work with nature and not against it. Nature is older, wiser and stronger than any person or structure. To keep nature happy, healthy and friendly, choose to be considerate in the following ways:

### 1. RESPECT THE EARTH.

Place structures onto the land and among the plants, trees, and streams so that natural beauty stays in place. Protect parks, farms, fields and natural landscapes whenever you can. Don't put things into the ground that could be destructive, such as chemicals and other man-made objects that will harm the soil, plants and animals.

### 2. RESPECT THE WATER.

Save as much clean water as you can for important things like drinking, washing and irrigating. Collect rainwater from the roofs of structures so it can be used for other needs in the structure or garden instead of letting it wash away the topsoil or be put into underground pipes that take it far away. Where needed for pathways or parking areas, cover the ground with materials that still let the rainwater soak in and feed the plants and trees.

### 3. RESPECT THE AIR.

Create structures that don't need a lot of energy to make them comfortable and warm. Most of the electricity that comes from power plants is made from burning coal which pollutes the air. Structures that are better insulated against the cold in winter and better ventilated with natural breezes in the summer will need less energy for heating and air conditioning. This helps the air inside and outside of the structure.

### 4. RESPECT THE SUN

Let the sun help light the inside of your structures instead of using lots of electric lights. To collect heat and light for winter face the structure to the south. You can use this side to have the most windows. For summer, you can use an overhang to block the sun when you don't want additional heat. If the summer sun heats up the side of the structure too much, plant big leafy shade trees to block the sun's rays.

The sun and trees work well together. In the fall, these trees will drop their leaves to let the sun warm up the structure in the winter time. Make roofs, sidewalks and driveways with light colors so the summer sun will not make them too hot.

### 5. RESPECT THE WIND.

Put structures on the land in places that protect them from cold wind in the winter. Plant evergreen trees on the side of the structure where they can block the winter winds. Try to let the breezes get into or around the structure in the warmer months of the year to help cool things off. **TIP:** Do an online search for prevailing winds in the Cincinnati area.

### 6. RESPECT MATERIALS & RESOURCES.

When we buy materials that are made or sourced close to a project, we invest in our local economy and reduce transportation costs and expended energy. Less miles to travel also reduces the amount of carbon emissions from trucks and semis. Whenever possible, reduce, reuse and recycle materials and resources.

### 7. RESPECT TREES & OTHER LIVING THINGS.

Try to make structures fit into the landscape without removing many trees, plants and other living things. All of nature's creatures need to have places to live and people can't live well without them. Trees help create the air that people and animals need to breathe.

### 8. AND OF COURSE, RESPECT PEOPLE.

Structures are made for people to use and live in. Make buildings bright, comfortable and safe. Make them out of things that help people stay healthy. Make them strong and long lasting because people spend lots of money and use lots of resources to build them. And, probably one of the most important things is to make them beautiful for people and for Mother Nature.

— Joel Elliott Stout, AIA, Committee On The Environment, November 17, 2000 (adapted)



## DRAWING TO SCALE

**LEARNING OUTCOMES**

- Students will understand scale as it is used in the industry and how they can utilize it in building their model.

**MATERIALS NEEDED**

- Digital Presentation 5
- Notebooks
- Pencils
- Drafting paper, if available  
*(they can also create their own)*
- Masking Tape
- Flat Ruler
- Pipe Cleaners

This is another section that can seem ambitious for some teachers. This is a good one to do with the volunteer. Start with the scale figure activity. Take it step by step with your students and understand that they may have a difficult time with it. Understanding this section will make a huge difference when they go to build their models, but it is not the end all - be all of the program.

Again, if you can't cover it all, try to pick out the activities that you feel are most useful for your students. You know them the best, you know what they are capable of and what is too advanced. Let them leave their comfort zone, but this section should not be creating unnecessary stress for any student.

**VOCABULARY**

**Scale** - The ratio of a distance on a map to the corresponding actual distance; the ratio of a linear dimension of a model to the same dimension of a full-scale original



# DRAWING TO SCALE

## USING ARCHITECTURAL AND ENGINEERING SCALES

An architect's or engineer's scale is a specialized ruler designed to facilitate the drafting and measuring of drawings such as floor plans and orthographic projections (three-dimensional objects represented in two dimensions). Because the scale of such drawings are smaller than life-size, an architect's or engineer's scale features multiple units of length and proportional length increments. Scales may be flat, with 4 scales, or have a symmetric 3-lobed cross-section, with 6 scales.

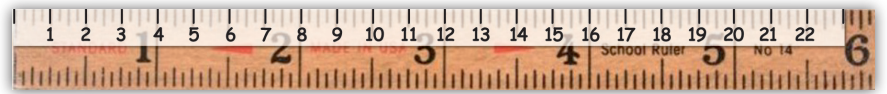
In the United States, architectural scales are marked as a ratio of 'x' inches per foot, typically written as  $x'' = 1'-0''$ . For example, one-quarter inch measured from a drawing with a scale of "one-quarter inch per foot" or  $1/4'' = 1'-0''$  is equivalent to one foot in the real world (a scale of 1:48). Another example, one inch measured from a drawing with a scale of "one inch per foot" is equivalent to one foot in the real world or  $1'' = 1'-0''$  (a scale of 1:12).

If you do not have architectural scales, the students can create their own by placing masking tape over a flat ruler, and marking off the increments to create a scale to use for measuring. Following are instructions on how to make a  $1/4'' = 1'-0''$  architectural scale (*you can adjust for other scales,  $1/8'' = 1'-0''$ , etc.*):

### MATERIALS NEEDED:

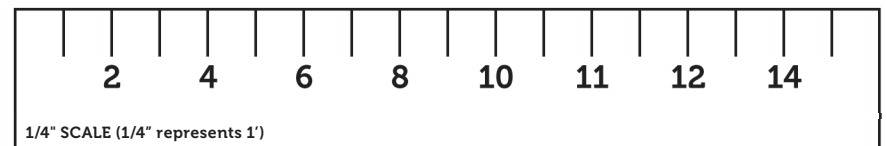
- Flat ruler (plastic, metal, etc.)
- Masking tape
- Sharp pencil or fine-point pen for marking

1. Place masking tape over the length of a flat ruler that has 16 markings per inch.
2. Starting at zero "0", for every 4 markings (or  $1/4''$ ), create a new mark that will represent 1'-0".
3. Going back to zero "0" and from left to right, number each new mark that you made sequentially so that each one represents one foot. You should have 4 'feet' per inch. If you mark all the way to 12", you will have 48 'feet'.
4. It should look something like this (not shown to scale):



5. Now you're ready to use the architectural scale you just created for your project!

You can also create a paper scale and photocopy for student use:



*In SCALE, this straight edge is 16 feet long. Each mark represents 1 foot.*

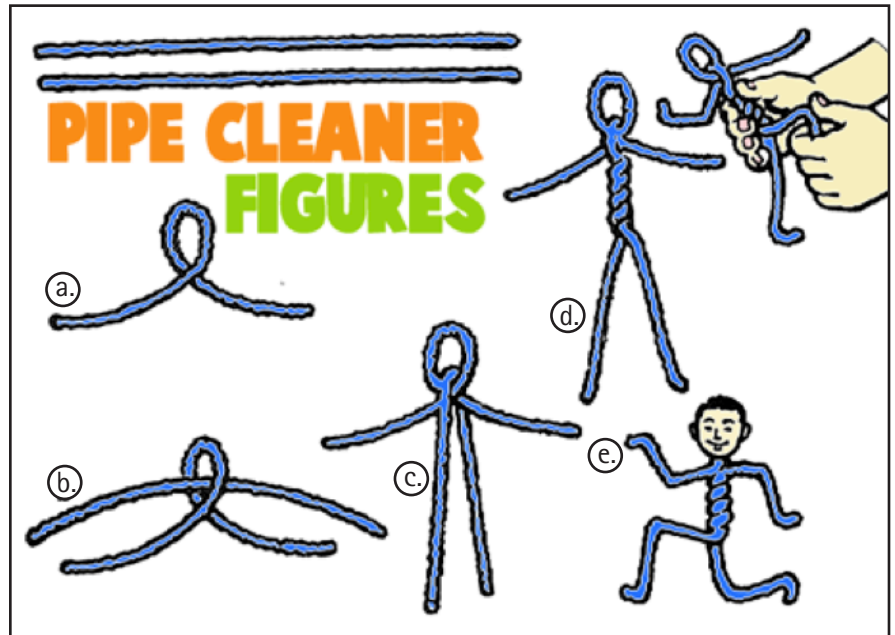
*For more printable scales, go to [www.printablerulers.net](http://www.printablerulers.net)  
Select 'Architect Scale 12-inch Ruler'. Requires legal-sized, 8.5" x 14", paper.*



# SCALE FIGURE ACTIVITY

In this activity, students create a figure that can be kept and used as a scaled object for drawings and models. If you do not have pipe cleaners, you can also create a "flat" scale figure from paper, cardstock or other material.

**OPTION 1:** To make these figures, you will need 2 pipe cleaners, face cut-outs (optional), and glue (optional). Carefully follow the illustrations shown at the right to make the pipe-cleaner figures. Go from illustration a. to e. Glue faces to heads of figures (optional). Have each student twist two pipe cleaners as shown above to resemble a human figure. Students should measure and cut their figures, estimating how tall a house would need to be to fit the figure's scale. When making a drawing or model, use the figure to make adjustments as necessary to be sure that the figure fits.



**OPTION 2:** Give each student one pipe cleaner to be cut and twisted to resemble a human figure. Students should measure their figures and estimate how tall a space would be to fit the figure's scale; they can make a drawing of their learning space, adjusting it as necessary to be sure that the figure "fits" (doorway, steps, windows, ceilings, walls, etc.) This figure can be kept and used as a scale determinant for further drawings and constructions.

*From 'Architecture in Education: A Resource of Imaginative Ideas and Tested Activities' by the Center for Architecture, Philadelphia, PA.*

**NOTE:** A 6'-0" tall person at 1/4"=1'-0" scale would be 1 1/2" tall. A 4'-0" tall person at 1/4"=1'-0" scale would be 1" tall.







# DRAWING TO SCALE

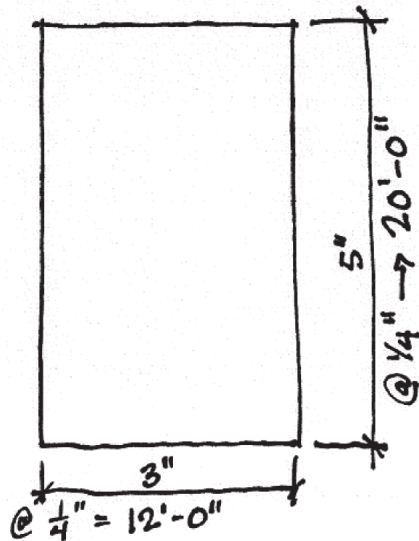
## DRAWING ACTIVITY

Scale can be a tricky concept to get across, but this multi-part activity will help you and your students to understand and be able to create scaled drawings & models.

### MATERIALS

- Architectural Scales / Rulers
- Each Student: standard 12" ruler, blank piece of paper - Lined or Graph paper work well too.

Copy the sketch below onto the board, large enough for students to read:



### PART 1: INTRODUCING DIMENSIONS

*Verbal Introduction:* Architectural and engineering drawings show how big things need to be, so they're labeled with the dimensions of all the parts so the builder can build it. (an example from your volunteer would be helpful to have on hand) This is how dimensions are written on a drawing.

Walk through the parts of the dimension notation in the drawing you copied onto the board.

### PART 2: INTRODUCING THE CONCEPT OF SCALE

*Verbal Introduction:* What does it mean when we say that drawing is "to scale"? Since we can't draw a building as big as it really is (your school building won't fit on even a large piece of paper!), we 'shrink' it down so it fits into a manageable picture, but we still need to be able to measure it as we work on the design. So, we shrink it down by using a ruler in a new way: an inch or a fraction of an inch represents one foot of length.

This can be done with a regular ruler (with a bit of mental math); architects usually use something called an ARCHITECTURAL SCALE. == *pass around your scales* == It's a special kind of ruler that is marked so that when you read 1, 2, 3, etc., instead of inches, they are actually 'feet', just shrunk down like a dollhouse or matchbox car. The smaller the fraction of an inch that is used to equal a foot, the smaller the "scale" of the drawing.

Another example of something 'scaled down' are model train sets. They're labeled differently, (O, H, HO, G, N, etc.), but each of those 'scale' designations represents a fractional scale, so that if you get parts from different places, getting the same scale makes sure they will all fit together.

1. Ask students to use the ruler to draw a rectangle in the middle of the page that is 3 inches wide and 5 inches tall.
2. Have students measure the box they drew using the 1/4" edge of the Architectural Scale, and have them write down the dimensions in feet and inches. (for younger students, do this larger on the board with them, so they can see and copy). The box will measure 12'-0" wide, and 20'-0" tall at 1/4"=1'-0" scale. Ask students to check out how big the box is at other scales. How big is it at 1/8"=1'-0" or 3"=1'-0"?



# DRAWING TO SCALE

## DRAWING ACTIVITY

### PART 3: DRAWING YOURSELF TO SCALE

#### MATERIALS:

##### K-6

- Roll-paper (or large sheets) for making full-size outline tracings of kids

##### K-12

- Architectural Scales
- Standard 12" Ruler
- Tape Measure
- Each Student: DRAWING TO SCALE STUDENT HANDOUT (next page), and Pencil

##### K-6

1. Create full-size outlines of each student on roll paper. Arms should be down to the sides. Feet should be flexed, with the soles of the shoes at the bottom edge. Before they get up, draw horizontal lines at the ankle, knee, wrist, elbow, shoulder, chin, eyes, and top of head, similar to the Student Handout. Have them write their names on their outline's 'shirt'.
2. Hang the tracings on the wall with the "feet" on the floor. (point out now they now have "elevations" of themselves at "full-scale" meaning the drawing is the same size they are. It's a really BIG drawing! Ask, "Can you draw the school building or your house at "full scale"?)

##### K-12 (6th grade and up could start here)

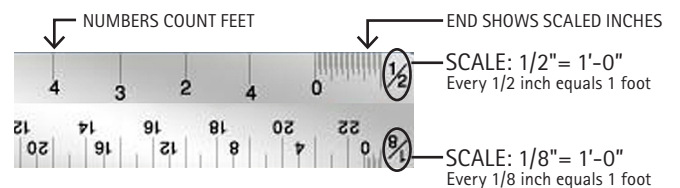
3. Have students pair off and measure themselves (or their full-size elevations) to fill out the DRAWING TO SCALE STUDENT HANDOUT. As they work, check to see that they are writing the dimensions with proper notation (from "Part 1: Introducing Dimensions" activity).
4. Once the dimensions are filled out, have them draw themselves in the graph paper section of the handout, using the 1/4" side of the architectural scale. You may need to walk through the scale translation of a few dimensions of yourself or students on the board to show the process.

### DRAW YOUR CLIENT TO SCALE

When students research their client, have them find or estimate their client's height(s) and draw their client to scale next to them on the DRAWING TO SCALE STUDENT HANDOUT. A scaled, cutout figure of their client will be helpful when they start building their models. You can also have them create a Pipe Cleaner Scale Figure (see 'Scale Figure Activity').

### PART 4: HOW BIG IS BIG ENOUGH?

Have students measure and evaluate a few spaces that they use for studying different subjects. How much space do you really need for these activities? Green design utilizes the concept of efficiency, not just in regards to energy, but also in materials. Smaller structures use less material. How small of a space could someone learn in? Can some rooms be used for more than one purpose? Why or why not? TIP: Send students on a web quest for examples of small, efficient learning spaces.

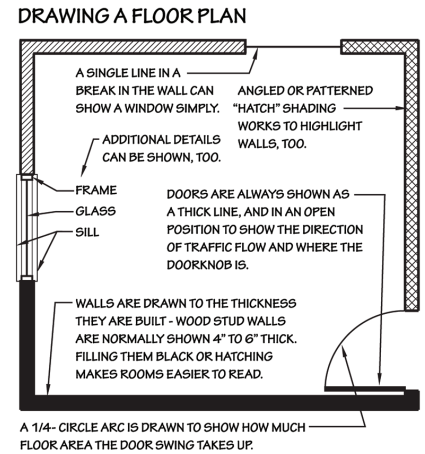
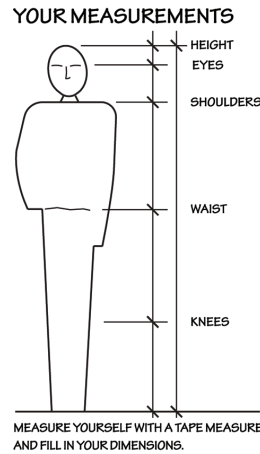




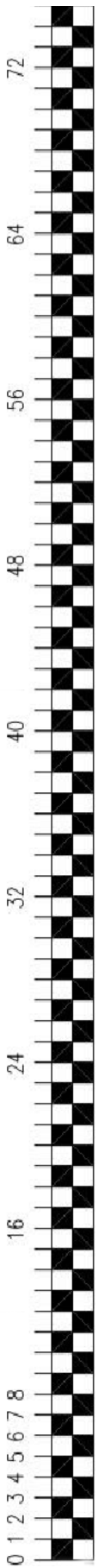
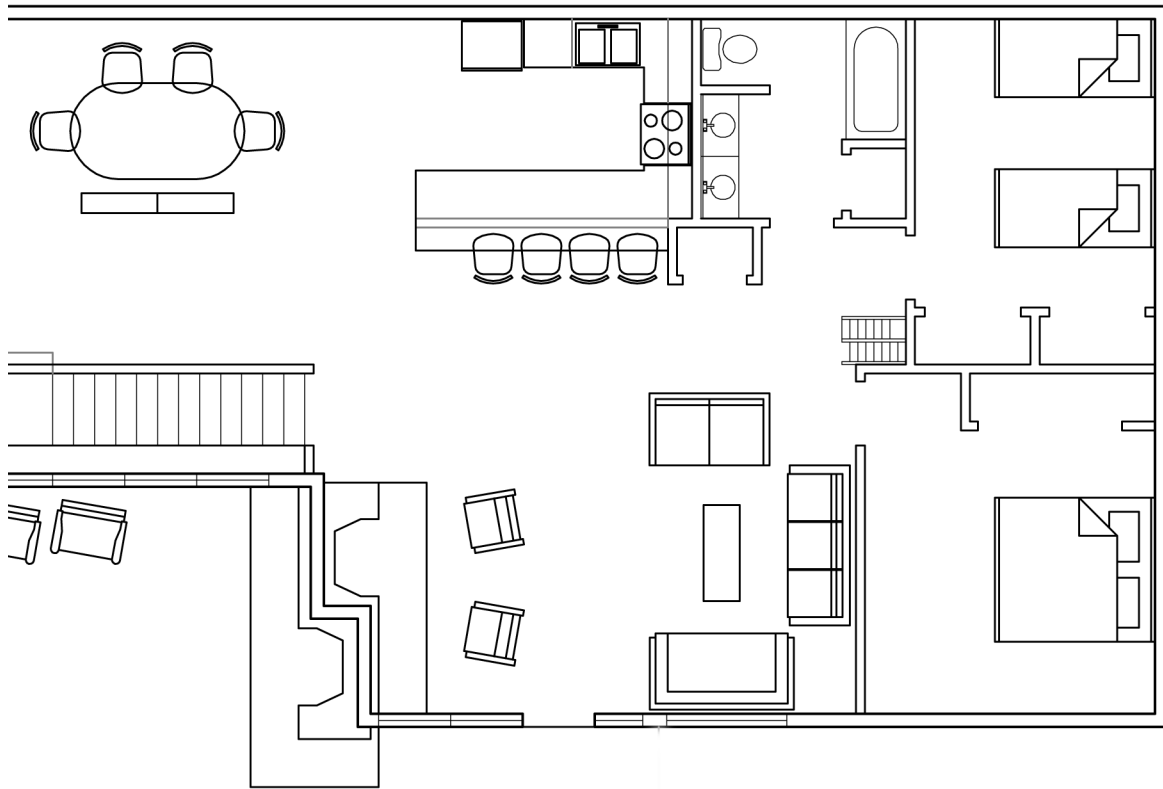
# DRAWING TO SCALE

## STUDENT HANDOUT

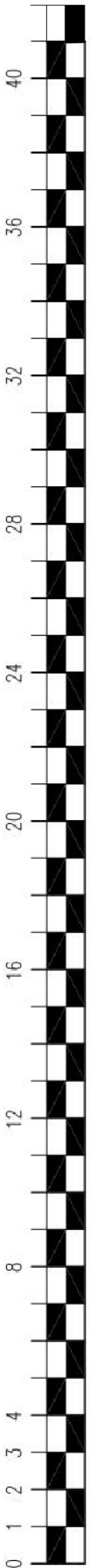
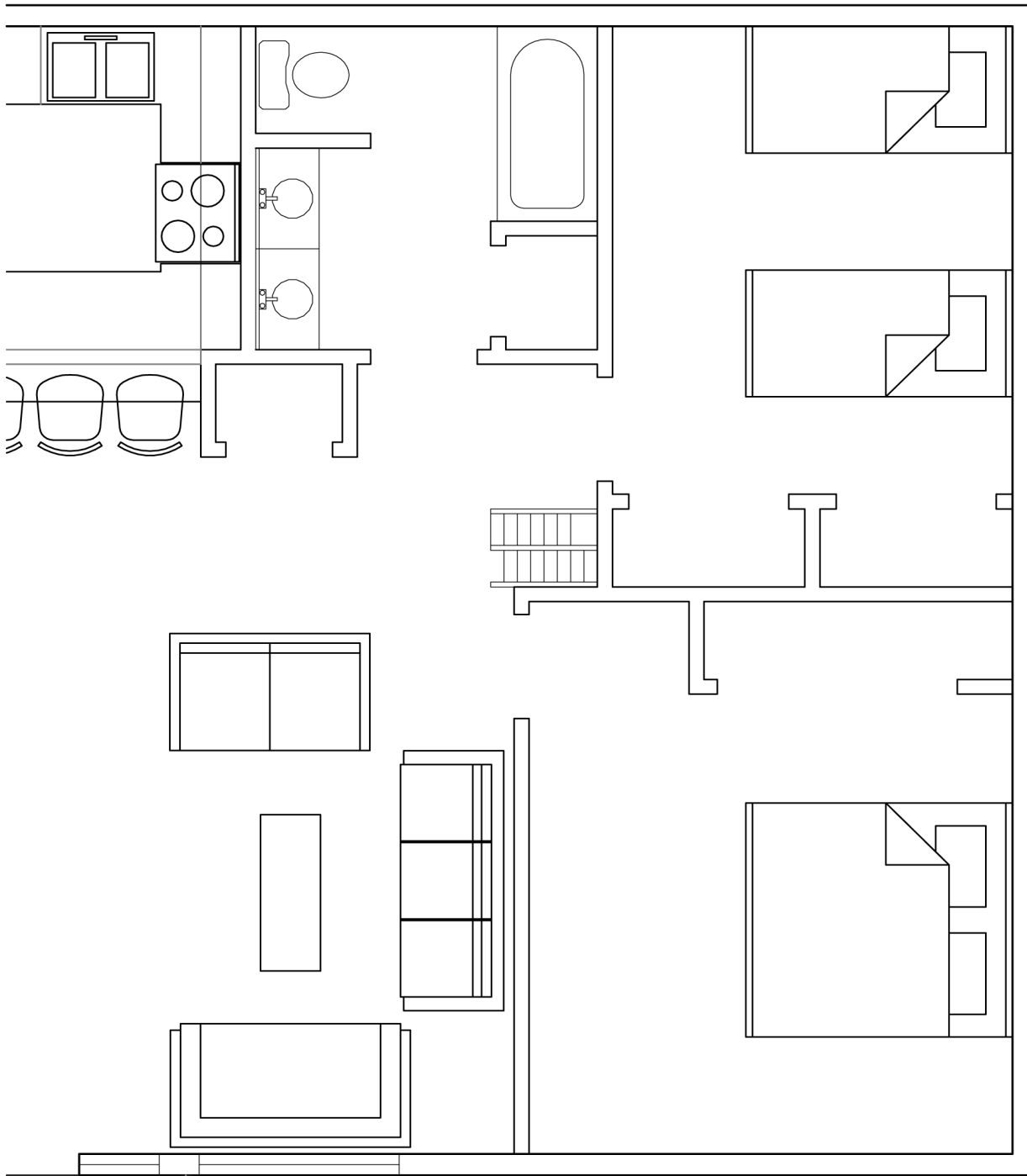
1. Have students measure their classroom, or bedroom at home, and draw a floor plan and the elevation of a wall with a window in it.
2. Evaluation – Have students write about their space. Is your room comfortable for the activities you do in it? Would it be too big or too small for other activities? Why?



YOU	SCALE: 1/4"=1'-0"	YOUR CLIENT
	<p>AFTER YOU HAVE YOUR MEASUREMENTS, SKETCH A SCALE IMAGE OF YOURSELF ON THE LEFT.</p> <p>FOR YOUR CLIENT, RESEARCH OR ESTIMATE THEIR MEASUREMENTS.</p> <p>COPY OR TRACE YOUR SCALED CLIENT TO CARDBOARD AND CREATE A CUTOUT FOR YOUR DRAWING WORK, AND/OR A STAND-UP FIGURE FOR YOUR MODEL.</p>	
<p style="writing-mode: vertical-rl; transform: rotate(180deg); position: absolute; left: -50px; top: 50%; font-weight: bold;">YOUR ROOM</p>		



FLOOR PLAN EXAMPLE  
SCALE: 1/8"=1'-0"



FLOOR PLAN EXAMPLE: SAME PLAN AT DIFFERENT SCALE  
SCALE: 1/4"=1'-0"

# PLAN, SECTION & ELEVATION

## DRAWING ACTIVITY

### LEARNING OUTCOMES

- Students will draw a plan, a section, and an elevation to understand how this applies to the built environment.

### MATERIALS for each team or table of students:

- 3 green peppers
- a cutting board
- a knife (you can also pre-cut the peppers and hand them out one at a time as you go through the activity)

### MATERIALS for each student:

- a pencil
- a blank sheet of paper oriented horizontally and creased in thirds  
*When their papers are named & folded, walk through the instructions:*

*NOTE: The activities in this section are designed for you to conduct with your class. Directions to you, the teacher, are in italics. These would also be appropriate for your volunteer's return visits. Ask your volunteer to bring in any examples of drawings or models from their work or classes.*

Architects, Contractors and Designers use three main kinds of drawings to show what designs look like and how they are built. These are the PLAN, the ELEVATION, and the SECTION.

Introduce this to students and write the words, "plan" "section" and "elevation" across the board, leaving room for you to sketch the pepper beneath each word along with them.

### DRAWING ACTIVITY INSTRUCTIONS:

1. Set the first **uncut** pepper on the desk or table in front of you. Crouch down and look at it with your eyes level with the **side** of it. What you see is the **ELEVATION** of the pepper. Draw what you see in the **first** section of the paper. An **elevation** is a drawing of the **side** of a building, and is a direct, **perpendicular** view to what you are seeing and drawing.



ELEVATION

2. Slice the second green pepper in half **horizontally**. What you see when you look **down** into the bottom is the **PLAN** of the pepper. Draw what you see in the **top half of the middle section** of the paper. When you draw the plan of a building, you are showing a horizontal "slice" at approximately four feet above the floor. When you look directly **down** at the top of the **un-cut** pepper, what you see is the "ROOF PLAN". Draw the roof plan of the pepper **below the floor plan**.



PLAN



SECTION

Try to orient the shape of the pepper the same way for both drawings. On the **Floor Plan**, shade in the thickness of the "walls". This shading is called "poche".

3. Slice the third green pepper in half **vertically**. When you look at the cut side of either half, you see a **SECTION** view of the pepper. Sections show **vertical** relationships between spaces in a building, and the walls beyond the "cut line" can be drawn in elevation within the section. Just like the plan, it's a "slice" through the object— shade in the thickness of the walls, roof and floor like you did for the walls on the plan.



**LEARNING OUTCOMES**

- Students will understand what a site is in regards to the built environment and the process that goes into selecting your site.

**MATERIALS NEEDED**

- Digital Presentation 2
- Notebooks
- Pencils

Once students have researched where their bridges will go, use the worksheet on the following page to help them plan different aspects of their bridge.

**RESEARCH**

- Find several examples of your selected bridge type(s). You could search the internet, find bridges in your community to take photos of, or use books from the library.
- Sketch a view of your bridge from above (plan view) (7-12th graders, your plans should be to scale). THEN, each team member should draw their ideas for what the bridge would look like from the side(elevation view). Decide with your team if you'll use one idea or a combination of several designs.

**SELECT SITE**

Your site can be anywhere in the world, or even an imagined place.

For realistic locations, use:

- Google Earth: [www.google.com/earth/](http://www.google.com/earth/)
- CAGIS (Cincinnati Area Geographic Information System): <http://cagisonline.hamilton-co.org/cagisonline/index.html>
- LINK-GIS (Northern KY Geographic Information System): [www.linkgis.org/lghome](http://www.linkgis.org/lghome)
- Your local county auditor's office or website e.g.: [www.hamiltoncountyauditor.org](http://www.hamiltoncountyauditor.org)
- Physical maps also work great for this.

**ANALYZE & DOCUMENT THE SITE**

What is the site like? Discuss the impact of building on a particular site. Students should think about features they want to add as well as existing conditions.

**NATURAL CONDITIONS**

- Topography – Is the site flat? gently sloping? steep?
- Vegetation – Are there existing plants (trees, grass, bushes, gardens)?
- Climate – Is the site sunny or shady? Where does the sun rise and set?
- Geology/Hydrology – What is the ground like? Wet, dry, rocky, sandy?
- Wildlife – Are there animals that live where the site is? Deer? Birds?
- Natural features – Waterfall, stream, hill, valley, etc.

**BUILT ENVIRONMENT**

- Land use – study the adjacent built structures, if any exist.
- Traffic/transit – autos, people. Are there sidewalks, roads or paved areas? Is there a bus stop nearby?
- Utilities – Do you see telephone poles, electrical wires, manholes, gas meters?
- Historic – Is it in a neighborhood made up of buildings that are old?

**DOCUMENT THE SITE**

- Take/find photos of the site.
- Draw a map so you can indicate features of the site while you walk around
- DRAW: show the shape of the existing site on drawing paper. Use the compass to mark North on your drawing. Note the time of day and the position of the sun. Measure and mark where the main features of the site are located, including natural features and the built environment.

**VOCABULARY**

**Site** - an area of ground on which a town, building, or monument is constructed



# BRIDGE BUILD GUIDE

## STUDENT HANDOUT

Name(s): \_\_\_\_\_ Grade: \_\_\_\_\_  
\_\_\_\_\_ Teacher \_\_\_\_\_

### ■ ■ ■ ORGANIZING & DESIGNING

Describe your bridge in each of the following areas. If needed, use a separate piece of paper for each.

#### SIZE:

What dimensions do your bridge need to be?

Width \_\_\_\_\_

Length \_\_\_\_\_

Height \_\_\_\_\_

Weight \_\_\_\_\_

#### SHAPE:

Which bridge type will you use? Bridge Types: Circle one or more types to incorporate in your design.

Beam Arch Truss Suspension Cable-stayed Other

What other shapes will be used to make your bridge? \_\_\_\_\_

#### LOCATION:

Where is your bridge? (indoors vs. outdoors; rural vs. urban vs. natural; what is it over) \_\_\_\_\_

#### MATERIALS:

What materials will you need to build your bridge? (keep in mind that your resources are very limited) \_\_\_\_\_

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## BRIDGE BUILD

## INFORMATION, TIPS &amp; RESOURCES

Common *MISTAKES*:

1. Using a single sheets of balsa for roadway (solution: cut into strips)
2. Making outside width 5.0 cm instead of inside dimension
3. Making overall length 40 cm instead of SPAN (between pedestals)
4. Forgetting 2.0 cm height requirement at 40cm width
5. Not allowing room for horizontal bars to sit on the test frame.

## BRIDGE BUILD TIPS

1. Use a small balsa wood saw (about \$4) instead of an X-Acto knife to make cuts.
2. Cut small notches to connect bridge components.
3. Use basic carpenter's glue (yellow wood glue).
4. Yellow glues contain aliphatic resin, used in the majority of winning bridges.
5. Fewer pieces mean fewer problems
6. Keep pedestals (feet) simple.
7. Clamp glued pieces for about a half an hour (use protective strips to avoid damaging the balsa). If you don't have clamps, you can use clothes pins. C-type and plastic grip-clamps are inexpensive and available at Home Depot and Lowes.
8. Design for strength at the load application point.
9. Construct roadway of thin, narrow strips of balsa.
10. Don't glue down ends of roadways – they usually bend upwards under load.
11. Use minimal support under roadway, except at load application point.
12. Roadway must support a small Hot Wheels type car.
13. Most bridges bend inwards (as viewed from one end); consequently they require horizontal bracing.
14. Double-check that a 40 cm-long board will fit between the pedestals (feet) of your bridge.
15. Double-check that a 5 cm cube will fit underneath your bridge AND along your roadway. You can make a nearly perfect 5cm cube from Lego bricks.
16. Do not cover your bridge with any material. Glue should be used only to JOIN components
17. Use light sandpaper (#150 or higher) to gently clean your bridge and remove excess glue.

## 3D MODELING

SketchUp 3D Digital Modeling: <http://www.sketchup.com/3Dfor/k12-education> SketchUp® is a user-friendly 3D modeling program made available online for FREE (limited edition). In previous years, several classes have utilized this visualization tool successfully. A little time on the tutorials provided on SketchUp web pages can get students ready to build their models in cyberspace, and even upload them to the 3D Warehouse site for all to see! If you are uploading models, please use "DLAB2017" in the front of the file names so they stay together.



# BRIDGE BREAK RULES

**In order to compete in the Bridge Break Competition, all rules must be followed. Any bridge that does not satisfy each requirement will be disqualified.**

## BRIDGE CONSTRUCTION RESTRICTIONS

1. Materials used in the construction of the bridge shall consist of only commercially available rectangular balsa stock, wood glue and 100% cotton string.
3. The total mass of the bridge must not exceed 100.0 grams (g).
4. The bridge shall contain no element wider than 1.0 cm (3/0") nor thicker than 0.65 cm (1/4"). Two or more elements, each separately meeting this requirement, may be laminated together to construct members exceeding these dimensions.
5. The bridge shall allow a 5.0 cm cube to pass underneath without touching the structure. The bridge shall also allow a 40.0 cm long by 2.0 cm high board to slide underneath (sideways) without touching the structure.
6. The bridge shall be "free standing".
7. An approximately level, smooth roadway surface, of minimum length 40.0 cm and above the 5.0 cm mark, shall be provided, across which a small metal car (e.g. Matchbox, Hot Wheels) will roll when given a single, light push of the hand. This roadway shall have a minimum width of 5.0 cm and shall allow a 5.0 cm cube to pass freely along its extent. Note: the roadway materials must conform to rule #3.
8. No fastening mechanism except mechanical interlock of the balsa pieces or commercial glue is permitted. If string is employed (in the case of suspension or cable-stay designs), it may only serve as it's own connection, and not be a part of connections between balsa members.
9. The bridge design shall allow the 'standard test frame' to be placed on the roadway surface with the load support rod(s) extending beyond the bridge sides.

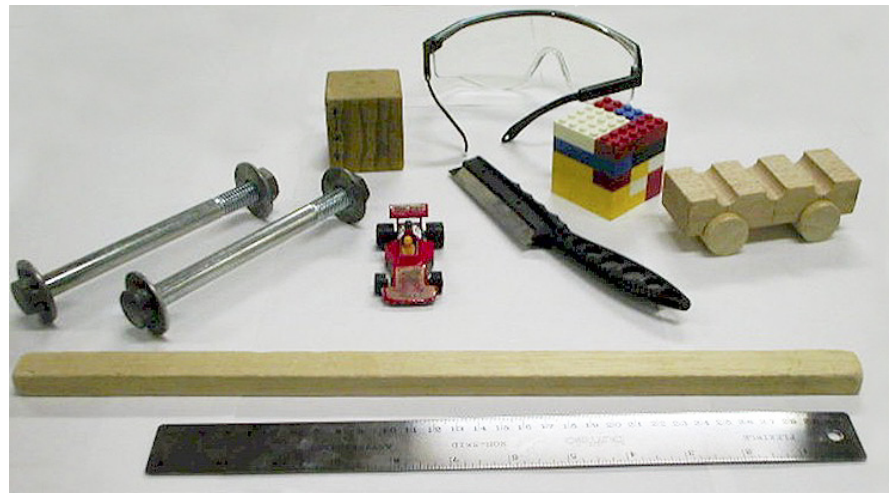
# IN-CLASS BRIDGE BREAK TEST

## BRIDGE BREAK TESTING ITEMS

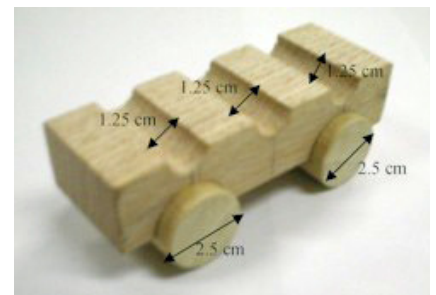
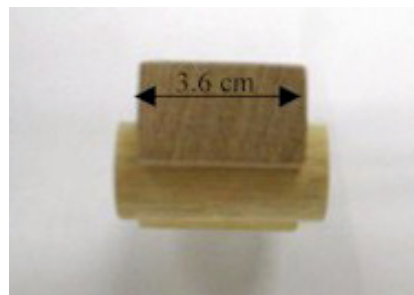
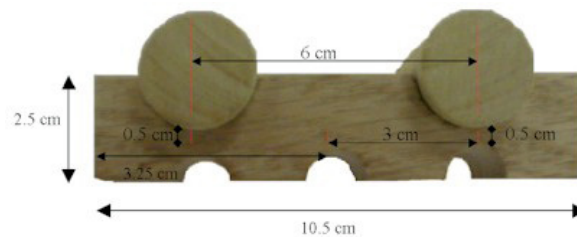
We recommend testing your bridges to breaking about half-way through the build process. This helps students understand the pressure points in their bridge design and gives them time to reanalyze and rebuild.

If you will be testing in-class and re-building, below is a list of items you will need:

- Standard Test Frame
- 5 cm x 5 cm block
- Ruler
- 40 cm x 2 cm x 2(+) cm board
- Safety Goggles (*a pair for everyone nearby*)
- Matchbox Car
- (2) 1/2" x 10" long bolts w/ (2) washers and 1 nut, each
- Not shown: Bucket, Wire Hooks, Metal Weights, Dry Sand



Measurements of Standard Test Frame to build your own:





# BRIDGE BREAK



## TESTING TO FAILURE

1. The bridge pedestals shall be placed on level surfaces separated by approximately 35 cm. These surfaces shall be level with respect to each other.
2. The standard 'test frame' will be placed on the roadway over the center of the bridge span. Depending on the bridge design, the load applied to the bridge shall either be suspended from a single 1/2" diameter rod placed in the center slot of the test frame, or from two such rods placed in the outer slots. Where either option will work, the judge(s) shall decide on the method to be used.
3. A container shall be suspended from the load-supporting frame. To this container (which may be pre-weighted with steel weights as warranted in the opinion of the judge(s)), **dry sand and/or steel weights shall be added at a slow, steady rate, until either an audible cracking sound together with visual evidence indicates the failure of some structural member or the glue joint of the bridge, or until a suitable reference point on the roadway at the center of the span has been lowered by more than 1.0 cm.** A competitor may not participate in the addition of weight to his/her own bridge. All decisions of the judge(s) are final.
4. The total mass of the test frame, container, hanging devices and container contents shall be recorded as the competitor's score.





# ARCHITECTURE AND DESIGN VOCABULARY

**BUILT ENVIRONMENT:** Human-made surroundings, such as buildings, structures, parks, streets, and bridges

**CARDINAL DIRECTION, CARDINAL POINT:** One of the four principal compass points: North, East, South and West also designated by N, E, S and W

**CLIENT:** A person or group that uses professional advice or services, for example from an accountant, architect, engineer, etc.

**CROSS SECTION:** A view into the inside of something made by a plane cutting through it

**CONSERVE:** To preserve and/or use the earth and resources in such a way as to avoid waste

**DESIGN PROCESS:** To create for a particular purpose or effect, usually in an arrangement of parts / details.

**DURABLE:** Products that are long-lasting and require little maintenance

**ECOLOGY:** The study of the relationships of organisms to one another and to their physical surroundings.

**ECOSYSTEM:** A community of organisms (plants, animals, microbes) in conjunction with the nonliving components of their environment

**ENERGY SMART:** Meeting your energy needs cost effectively and with the least impact on the environment

**ENVELOPE:** The skin of a building— including the windows, doors, walls, foundation, basement slab, ceilings, roof and insulation— that separates the interior of a building from the outdoor environment

**ENVIRONMENTAL IMPACT:** The effect of materials on the environmental quality inside your home and to the outdoor environment and atmosphere

**FOOTPRINT:** Land area taken up by a building

**FOSSIL FUELS:** Carbon-rich deposits in the earth, such as petroleum (oil), coal, or natural gas, derived from the remains of ancient plants and animals and used for fuel; non-renewable energy

**“GREEN”:** Making environmentally friendly choices that use our natural resources for present needs without depleting those resources for future generations

**INSULATION:** A material that prevents or reduces the passage, transfer or leakage of heat, electricity or sound

**LEARNING SPACE:** the product of a design process created from the relationships between forms of space and style of learning.

**LOCAL (MATERIALS):** Materials extracted/manufactured/produced within 500 miles of building site

**MODEL:** A three-dimensional representation of a person, thing or proposed structure of a smaller scale than the original

**NATURAL RESOURCE:** A material or supply such as timber, fresh water, or a mineral deposit, occurring in nature and with the potential for human use

**PROGRAM:** A list of types of spaces needed for a project and their associated areas, usually in square feet (area)

**RECYCLE:** To use again, especially to reprocess

**REGION:** An area with similar characteristics that separates it from other areas. Regions might be defined by criteria like common culture or language; climate; economic activity; or political connections. Regions have extremely fluid definitions that might be as small as a neighborhood or as large as a continent

**RENEWABLE:** Natural materials that can be rapidly replaced in the environment, such as fast-growing trees and agricultural products

**RENEWABLE ENERGY:** Energy derived from sources that do not deplete natural resources; examples include solar, wind, and geothermal energy from the Earth's core

**REUSABLE:** Products that can be used again or recycled once they are no longer needed or operable for their original purpose

**RURAL AREA:** An area of very little development, often characterized by agricultural uses or undeveloped land

**SCALE:** 1. The ratio of a distance on a map to the corresponding actual distance. 2. The ratio of a linear dimension of a model to the same dimension of a full-scale original

**SHAPE:** The form of an object or its external boundary / outline

**SITE, BUILDING SITE:** A place or area where something is, was or will be built

**SKETCH:** A rough drawing that can express an idea

**STORY, STORIES:** A floor or level(s) of a building

**STRUCTURES:** Elements of a built object that are combined and organized to hold the object together and keep its shape.

**SUBURBAN AREA:** A developed area located outside the denser urban center characterized by a separation of uses and within commuting distance

**SUSTAINABILITY:** Meeting the needs of the present without depleting resources or harming natural cycles for future generations; another way to say “green”

**TWO-DIMENSIONAL (2-D):** A shape that only has two dimensions and no thickness (x, y)

**THREE-DIMENSIONAL (3-D):** An object that has height, width and depth (x, y, z)

**URBAN AREA:** An area of dense or closely placed development, often associated with a street plan made up of blocks, and mixed uses; a city

**WATERPROOF:** Designed to prevent water from entering or passing through; impervious to water