# Structure in Architecture

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## INTRODUCTION

This curriculum unit is designed to give students an integrated interpretation of structures, structural elements, and their functions. This unit will help students make critical connections between standard science objectives taught in the classroom and the applications of those objectives in the real world of building structures. Students will engage in activities that will foster understanding of how principals of both math and science are incorporated in the design and construction of buildings. The unit is designed to give students an opportunity to explore basic principals and concepts associated with architecture through hands-on activities.

The ***experimental design method*** will be an important component of this unit and will be used whenever possible to investigate principles that govern how structures stand alone, respond to environmental factors, and function as efficient dwellings. Students will have the opportunity to identify different structural elements and make comparisons between architecture in their city in terms of style, structure, and the building materials used to create them.

## UNIT FORMAT

This unit is formatted to give the teacher the option to teach it as a whole unit or teach it in parts. To facilitate specialized vocabulary learning, a background and discussion section will precede the activity part of the lesson plan. This should give the teacher additional information on the concepts covered in the activity. The lesson plan portion of the unit will list the four main objectives covered in the unit. A focusing exercise, a main activity, and an extension activity will be presented for each objective in the lesson plan. The end of the unit will include an annotated bibliography and a list of objectives correlated to the state's scope and sequence objectives.

### Lesson Plan Activity Titles and Objectives: 1-4

1. **Geometry in Architecture:** The student will recognize geometric shapes in building designs and make three-dimensional models using geometric nets.

2. **Strength in Design-Statical Function:** The student will discuss the means in which a structure bears and transfers loads. They will use the experimental design method to test the effect of shape differences on the load bearing potential of linear forms.

3. **Evaluating Materials in Terms of Heat Resistance Values:** The student will examine ways in which heat is transmitted. Students will use experimental methods to

evaluate the effectiveness of heat blocking materials in used by builders to maximize inside comfort.

4. **Load Bearing Curves Arches and Domes:** The student will research arches and domes in history. They will investigate principles that govern these two structures.

**The Nature of Architecture**

James Neal, the author of *Architecture: A Visual History*, tries to answer the question, What is architecture? Is it art or science? Because the two elements combine in a building, it is hard to make a clear distinction between them. Without science, buildings cannot have the necessary structure they need to remain through the years. Sound structural designs allow us to witness the physical remains of architecture from the distant past.

Although architectural fashion has always been subject to the vagaries of individual taste, ultimately the aesthetic appeal of an architectural form must take into account the scientific analysis of how structures bear loads. Adding a pilaster to a corner of a building or pitching a hipped roof can be both beautiful and statically functional. This unit will help students understand the relationship between the aesthetics of architectural form and the use of statical elements. The ability to build beautiful structures that will remain for many years is a synthesis approach that involves the evolution of structural technology. Advances in technology have allowed architects to build stronger and longer lasting structures; new space frame materials have given the shopper a greater venue in which to satisfy personal taste. The advent of reinforced concrete, steel frames, and better expansion materials has made structures stronger, more spacious, and more functional.

**A Tour of Your City**

A tour around your city or town can give students an idea of how structures have evolved through the years. Architectural styles provide a visual chronicle of economic, political, and technological happenings in an area or during a particular period. A tour of your town or city will give students an opportunity to compare different architectural forms. It is interesting to see how different architects have different styles of design. The teacher could pick out structures or buildings on the tour that look different and have students discuss which elements in design, structure or even impressions make them different. For example they could contrast the ornate embellishments of Cram and Ferguson to the sharp symmetries of Philip Johnson. Cram and Ferguson were part of a team commissioned to design the Julia Ideson Building, one of the original buildings of Houston’s downtown library, built in 1926. Philip Johnson, whose work includes a trio of buildings on the campus of the University of St. Thomas starting in 1958, stands in stark contrast to the works of Cram and Ferguson.

By touring your town, students will be able to contrast old and new structures. Notes can be taken on factors such as geometric shapes of buildings, materials used to construct them, the placement of openings, the direction of porches or balconies, and the visibility and location of support elements. (*See Appendix.)*

## BACKGROUND AND DISCUSSION

### Activity One: Geometry in Architecture

Architecture is the designing and building of structures. A structure should be an expression of beauty and function. In order to achieve both beauty and structure in a design architects must have some artistic skills and must also have a good understanding of mathematical principals. Without detailed plans for construction, buildings would not be able to stand. Although the first methods of constructing buildings were probably developed by trial and error, today constructing buildings and other structures starts with designing a plan. Architects express their designs in the form of drawings or plans. These drawings are scaled dimensions of actual sized structures. The basic element in a plan is a point. Although a point has no dimensions (any length, width, or height), architects can extend a point to make a line. If the line is moved upward from itself, the line forms a plane or a flat surface. This flat plane has an area, which can be measured. It is probably easier to explain the forms found in architecture as a series of joined planes also having definite measurements. Thus, a three-dimensional structure can be expressed in terms of geometric principles such as spatial limits and shapes. For example, when a square is moved in a direction perpendicular to its surface, it becomes a space or a form with volume. An architect must be able to draw and visualize space in terms of area and volume. Most of the buildings or structures around us are polyhedrons. A polyhedron is a three-dimensional form whose surfaces are polygons. A polygon is a closed plane figure with at least three sides. The sides intersect only at their endpoints and no adjacent sides lie on the same plane (colinear). The polygons are faces of the polyhedron. An edge is a segment that is the intersection of two faces. There are five regular polyhedrons. They are called regular because all their faces are congruent regular polygons, and the same number of faces meets at each vertex. The polygons are the faces of the polyhedron. The lateral area of a form or figure represents the sum of the areas of the lateral faces---In building this lateral area would represent the sum of all its sides. The lateral base would represent the floor of the building and the sides of the building would represent lateral faces that a perpendicular to the base.

| Polygon | Number of Sides |
|---|---|
| Triangle | 3 |
| Quadrilateral | 4 |
| Pentagon | 5 |
| Hexagon | 6 |
| Heptagon | 7 |
| Octagon | 8 |

**Activity Two: Strength in Design/Statical Function**

The forms of the different architectural styles in your city and around the world are directly related to the systems of construction and the strength of the materials used during a certain time period. The huge stone pillars at Stonehenge in England, and the massive blocks of Khufu's pyramid in Egypt, have stood for thousands of years. Without detailed construction methods, including knowledge of load bearing systems, these structures would not have lasted so long. The mechanics of statics--the means in which structures bear loads--cannot be overlooked in the creation of architectural works of art. The type of load bearing systems that supports a structure directly influences the different styles of architecture seen in a period. The expression of load bearing elements in structures differs from one region to another and from one period to the next. Sometimes elaborate facades or unusual morphology hide the bearing structures in a building--the supports that hold them up are not always articulated in a building's shape. Putting basic structural elements together can create an incredible variety of structural systems. Structural designs are governed by natural laws that dictate the behavior of structural elements. Structural systems can be beautiful as well as functional. To achieve the ideal structural system architects carefully balance their design wishes with the availability of materials and basic physical principals. Physical principals and laws must be evaluated critically so that structural designs are stable and the elements that make them up are in equilibrium. Each element that makes up an architectural structure must be in balance or equilibrium with every other structural element in the structure so that it stays together and remains stable. The elements and the structures that make them up must be resistant to the forces that act on them.

Sir Isaac Newton explored principals of equilibrium and wrote down laws that explained these governing principles. Newton discovered that an object would reach a position of equilibrium if the forces all around the object, which act upon the object, were in balance. Up to the present, individuals have conducted studies on the relationship between forms in architecture and their load bearing construction. It can be said that the aesthetic appeal of any form ultimately depends on how the form performs statically. Architectural forms reflect stability, solidity, or the equilibrium of forces. To the casual observer, the statical framework of a structure may appear to form its morphology or shape. Sometimes looks can be deceiving and morphological elements are used only as decorative features not as elements of the building's load bearing frame. Thus the shape of the structure is relevant as a support only when it bears a direct relationship to statical function. The foundation elements that support buildings and other structures must be able to withstand the forces that act on them. The effect of forces acting on a load bearing element can cause deformation of the element in several ways. Based on the way in which deformation occurs to an element, five different modes of load transfer can be identified:

1. Load transfer by compression--when the resistance of a body to a load tends to decrease one of its dimensions.

2. Load transfer by tension--when the resistance of a body to a load tends to increase one of its dimensions.
3. Load transfer by bending--when the resistance of a body to a load tends to curve it.
4. Load transfer by shear--when the resistance of a body to a load tend to change the angle.
5. Load transfer by torsion--when the resistance of a body to a load tends to twist it.

It is important to note that a one-dimensional linear element may transfer loads only by compression or tension. Only two-dimensional surfaces are able to transfer loads by bending or by shear (Zannos). Finally load bearing elements can be classified according to how they respond to stress and forces because of a particular geometric form.

***Surface Forms:*** one whose two dimensions are clearly larger than the third. Curved surface forms include shells, folded plates, and membranes. Flat surface forms include slabs, walls, and disk-like shapes.

***Linear Forms****:* are defined as forms that have a minimal cross-section. Load transfer takes place linearly, along the axis of the element. For this reason, only tensile and compression stresses can develop within this type of bearing element.

***Beam:*** a linear surface element that acts on bending and shear; crucially important in determining the way in which the form operates as a bearing element. Beams in buildings are subject to forces of compression and tension because they have to support weight across a span.

***Column/pillar:*** a linear element that transfers loads to the base of a structure.

***Composite Forms:*** these forms incorporate straight, polygonal, or curved bearing elements with a statical function. They include nets, trusses, space frames, and various kinds of geodesic domes.

***Forms with a mass statical function:*** are those forms with a three-dimensional load bearing function in which all three dimensions are involved in the load transfer.

## Activity Three: Evaluating Materials in Terms of Heat Resistance Values

Early builders of homes and other structures relied chiefly on structural features and the strategic arrangement of space to maximize comfort inside the structures they built. A look around your city or even your neighborhood might disclose the ingenuity of early builders in designing structures in such a way that ventilation, cooling, and heating potentials are increased. Architects included features that added shading, openings that provided ventilation, and they used materials that decreased heat transmission.

When architects calculate the thermal behavior of a building or structure, the windows are considered separately from the regular walls because they behave like holes in the wall. They can quickly affect the overall comfort level of the structure. Glass windows or openings transfer heat by either conduction or direct transmission. Like all materials the ability of glass to conduct heat is measured by its insulation value. Even though insulated glass will reduce heat flow considerably, the heat transfer rate through glass is still several times greater than through a well-insulated wall. Regardless of glass's poor resistance to heat flow, solar radiation can be transmitted through it instantly. This gives glass areas a much greater influence on the heating and cooling potential within a building. When solar radiation strikes a window some of it will be reflected, some of it will be absorbed and some will be transmitted. The proportion of solar radiation that will be absorbed, reflected, or transmitted depends on the angle of the sun's rays that strike the glass. For instance, when the sun strikes the glass in a perpendicular direction, the transmitted component is large and the reflected component is small. At incidence angles greater than 60 degrees, the reflected proportion increases, and the transmitted proportion or component decreases. It is the transmitted component that influences the thermal conditions of space inside a structure.

**Shading** is an important consideration for builders. Shading can be used to reduce the amount of transmitted radiation into a closed space. Traditional shading devices have included overhangs, venetian blinds, and trees or bushes. Shading is very beneficial during seasons of overheating due largely to the positioning of the sun. Determining the exact periods of overheating in an area is obviously important to builders. Decisions on where and when to include shading can greatly affect the comfort level inside a closed space.

**Ventilation** is another important consideration for builders. Ventilation is the intentional introduction of outside air into a building to ensure the health and well-being of the occupants that inhabit it (Hill). The function of ventilation can be arranged in three categories:

1. Health Comfort ventilation
2. Thermal Comfort ventilation
3. Structural ventilation

Health comfort ventilation helps ensure the quality of indoor air by replacing it with outdoor air. Thermal comfort ventilation prevents bodily discomfort by removing excess skin moisture that ordinarily would decrease the dissipation of heat. Health ventilation replenishes oxygen supplies and prevents the toxic build up of carbon monoxide.

**Insulation** is the basic feature in a building's structure necessary to protect it from the changes in outside temperature. If properly designed, insulation can greatly increase the comfort level within a structure. Thermal insulators are those materials, which block or decrease the flow of heat. These insulation materials can drastically decrease the flow of heat through all three modes of transfer: radiation, convection and conduction. Insulation serves three purposes as it relates to the three modes of heat transfer. First, insulation may act as a reflection material that reflects electromagnetic waves of radiation. Secondly, it acts to trap air and other gases preventing these gases from transferring heat through convection. Thirdly, it acts to sieve out heat by providing a material that has a high resistance to heat transfer through conduction.

All insulation is rated according to its “U” or “R” value but it is also classified according to its physical characteristics. These classifications are largely determined by the physical properties of the materials that make them up. Some of the physical characteristics of insulation include low or high densities, high or low compressibility, stiff or loose consistency, frothiness, and reflective ability.

**Activity Four: Arches and Domes Compression Differences**

Whereas any body or work of architecture has a shape and must conform to the laws that govern standing bodies, the diversity found in architectural forms is impressive.

***The Dome***

A dome is a curved roof atop a base. Domes are the most impressive of a family of structures called form resistant because they owe their stability to their curved, continuos shape. A dome can be thought of as a series of vertical arches rotated around a vertical midpoint. Domes are able to carry to the earth or to their bases their weight and the weight placed on them. The imaginary arches that make up a dome are fused together and are never independent of each other. For this reason the arches of a dome cannot open up under load and do not need buttresses (ground structures that keep arches from collapsing). The horizontal circling of its surface acts like the bands around a barrel that keep the staves intact. Because of the cohesiveness of a dome’s side surfaces, they are very strong against gravity loads. The earliest domes covered primitive huts and were made of brick or stone. The ancient Romans used domes to top such circular areas as the Pantheon in Rome. The Pantheon has one of the largest masonry domes ever built, with a height and diameter of 43 meters. In the early A.D. 500s the invention of pendentives, curved triangular supports, allowed architects to place domes over square buildings. Previously, builders could only build domes on round buildings. One of the first large buildings to use pendentives was the church of Hagia Sophia in Constantinople, completed in 537. Renaissance domes, such as those erected on top of St. Peter’s Church in Rome and the Cathedral of Florence, are generally taller than earlier domes. The dome on St. Peter’s provided the model for the dome on the Capitol of the United States. Many mosques and Muslim tombs have domed tops. The Taj Mahal in Agra, India is an example of a domed tomb. Architects today have used huge domes to cover stadiums.

**HOUSTON ASTRODOME: The Astrodome in Houston was the first baseball and football stadium to be completely enclosed by a roof. At its highest point, the dome is 63 meters above the stadium floor. How does it compare to earlier domes?**

***The Arch***

The arch is a building form of great antiquity. The Babylonians used the arch in palaces, tombs, and temples. The Pelagians and Etruscans used the arch in gates, bridges, passageways, and tombs. The Romans used the arch freely in their secular structures, as in Colosseum and in the long line of aqueducts. In the Romanesque style the round arch and in the Gothic style the pointed arch were often used in sacred structures such as the great cathedrals of Europe. The pointed arch had a structural use, which was more important than the ornamental effect, as it minimized the outward thrust.

The support of an arch may be walls, piers, or columns. The capstones from which it springs or on which it rests are its imposts. The wedge-shaped pieces composing it are called voussoirs. The upper part of the arch is its crown. The portions near the impost are the haunches. The two lowest voussoirs are called spingers. The center of the crowning voussoir is the keystone and the inner outline or edge of the arch is called intrados. The outer line or edge is called its extrados and its under surface is called a soffit. The molded band, which often surrounds the opening, is called an archivolt.

## LESSON PLAN ONE

### Objective

The student will recognize geometric shapes in building designs and form three-dimensional models from geometric nets to a 1" reduced scale.

### Focus Exercise

The teacher will present a shoebox, cereal box, or some other container and ask the students to identify the total number of faces the container has. The teacher could ask for a volunteer to draw the container as a flat two-dimensional figure.

### Procedures

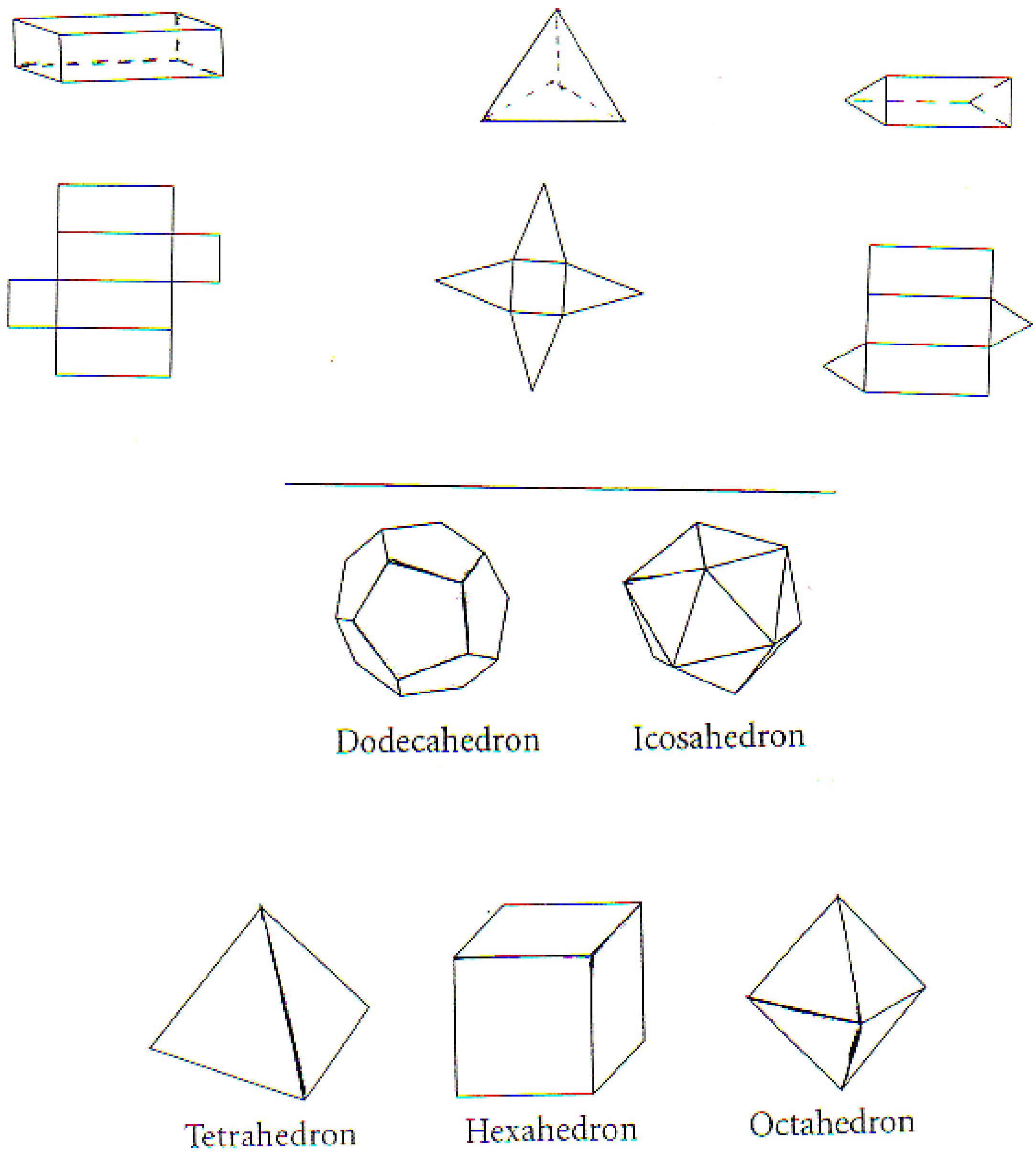
The teacher will explain to the students that a geometric ***net*** is a two-dimesional figure that can be folded or made into a three-dimensional model. The teacher will then ask students to discuss the following:

1. **How are geometric nets like architectural drawings of buildings?**
2. **How would a net of your classroom look;  your school?**
3. **How many faces would a tetrahedron net have; an octahedron?**

****Make a transparency of the net sample page (FigureA-1) and show it to the class after the discussion.***

(Figure A-1)

Geometric Nets and Platonic Solids




**Activity: Geometry in Architecture**
Time: (1) 1.5 class periods, 90-min. blocks
Group Activity: 2-4 students

***Rationale:*** An architect's ideas for a specific design usually find their first expression through sketches. Often much time can be saved if the architect can make a preliminary sketch of his ideas before they are committed to actual instrumental drawings. Cross/ sectioned paper (grid) is useful because it provides guidelines for the designs. Grid paper is very useful for sketching to scale since values can be assigned to the squares, and the squares counted to proportion. The terms planned for the top view of a structure and elevation for all view showing the height of the structure are useful when describing designs on paper. One-dimensional drawings can be described in terms of its three-dimensional shapes. Most of the buildings around you are polyhedra, the most common forms of which are the pyramid and prism. Regular polyhedra include the tetrahedron, cube, octahedron, dodecahedron, icosahedron, know as the five platonic solids.

***Materials:*** In this activity students will design a structure by first designing and scaling a geometric net. Each student group will be given the following materials:

> 2-3 large sheets of grid paper (use 4 squares per inch grid paper)
> large poster board (or large piece of cardboard)
> ruler (customary and metric sides)
> scissors
> roll of tape (masking tape)
> glue

***Procedure:*** After students have received their materials, tell them to draw a net in the shape of a six-sided polyhedron called a hexahedron (like a cereal box) onto their grid paper. Tell them that their nets when folded into a three-dimensional model should have the following dimensions:

> The two tops and bottoms (bases) should be 10’ x 10’. The lateral sides (standing faces) should be 10’ wide x 15’ long so that when the net is folded it will stand 15’ tall. Remind students that each ¼ square will represent one foot. Thus ten of the ¼ marks is equivalent to ten feet.

Direct students to cut their nets out and glue them to the poster board; after they have cut the poster board to the size and shape of the net, use the tape to hold the sides of the folded net together. The completed three-dimensional structure should be able to stand alone. Next, tell students they will make a second three-dimensional model, only this time their nets will be in the shape of a tetrahedron (pyramid-shaped). The base of the structure will be 10’ x 10’. Each of the triangles that make up the four lateral faces of the structure will have an altitude of 15 feet and a base-edge of ten feet. (The four lateral sides of your structure form four congruent isosceles triangles.)

1. Find the perimeter of one of the lateral faces of model one (the perimeter is the sum of the length of the sides).

2. Find the area of one of the lateral faces of model one (the area is the product of the base and height).

3. Find the lateral area of model one (the lateral area is the sum of the lateral faces).

4. Find the surface area for model one (the surface area is the sum of the lateral faces and the two bases).

5. Find the volume of model one (volume for this model is found by multiplying length, width, and height).

6. Are most of the buildings around you shaped like structure one or structure two? Why?

**Extension Activity**

Find the area of the lateral faces in your classroom. Make a net of your classroom. Substitute an architect scale and use the ¼ reduced scale in place of grid paper to design your net.

**LESSON PLAN TWO**

**Objective**

The student will discuss the means in which a structure bears and transfers loads. They will use the experimental design method to test the affect of shape differences on the load bearing potential of linear forms.

**Focus Exercise**

Cut seven cardboard strips 14 cm long and 2.5 cm wide. Glue four of the strips together to form a square frame. Glue the remaining three strips together to form a triangle frame. Ask students to guess which frame would be stronger if pressure were applied to them while they were held in an upward position. After several students respond, have one student come to the front of the room. While you hold the sides of the square frame so that it is standing upward from the desk, have the student use a pencil to gently press down on the square. Have the student stop applying pressure when the frame begins to buckle. Next, have the student apply pressure to the triangular frame while you hold its sides. When the sides of the triangle begin to buckle, stop applying pressure. Ask the student if there was any difference in the amount of pressure the two frames could take before buckling.

**Did one withstand more pressure than the others? Did shape make a difference?**

**Activity: Strength in Design/Statical Function**
Time: (1) 90-minute block
Group Activity: 3-4 students per group

***Rationale:*** Architects must know the compression strength of structural elements that support buildings. The foundation elements that support buildings must be capable of withstanding compression forces. When pressure is applied to an object such as the force of a structure on a supporting block, the block must be able to transfer the force of the structure to the ground. A load supporting straight element such as a column has forces of compression acting on it. In order for a column to support a structure it must have enough compression strength to remain stable and not move or crumble. Compressed forces seem to crush matter together. When a column is crushed by a force, the material that makes it up is pushed together.

**A straight element under pure compression is called a strut and is used mostly in bridges and roofs. When used vertically a strut is called a column.**

***Materials:*** In this activity students will use an experimental design method to test the effect of shape differences on the load bearing potential of linear forms. Each student group will be given the following materials:

bathroom scale
(1) large poster board
(1) small block of wood 12" long ( a 2 x 4 will do)
roll of masking tape
scissors
data table

***Procedure:*** After students have gathered their materials, tell them that they will be testing the compression strength of several cardboard columns of different shapes. Direct students to cut three strips from their poster boards 9" x 12" each. Have the students fashion the strips into columns. Each column will have a different shape. The first strip of cardboard should be rolled to form a cylinder-shaped column. The second cardboard strip should be folded to form a triangular-shaped column. The third cardboard strip should be folded so that it forms a square column. (Fold and then crease your cardboard strips to form the triangle and square columns). Use tape to keep the columns folded. Tell students they will measure the compression strength of each of the columns by placing them on the bathroom scale and pressing down on them with the wooden block.

Stand the cylinder-shaped column on the bathroom scale and place the wooden block on top of it so that it sits across the column, sticking out on both sides. (The scale should be placed on the floor.) One student from the group will straddle the bathroom scale, bending so that both hands or on either side of the wooden board. One of the other students should be in a position to see the needle of the scale. At the count of three, the student with his hands on the wooden board will slowly press down on the board, gradually increasing the amount of pressure on the column beneath it. As soon as the column begins to buckle, the student watching the needle of the scale will record the exact weight. Repeat this for the remaining two columns.

1. Use the following conversion values to convert the compression strength of each column from pounds to kilograms.

   $$1.0 \text{ kg} = 2.2 \text{ lbs}$$

2. Use the following formula to calculate the amount of force exerted on each column type before it crumbled.

   $$1.0 \text{ kg} = 9.8 \text{ N}$$

3. Which column had the greatest compression strength? Which column had the least amount of compression strength?

4. Use the following formulas to find the amount of area each column occupied. Find only the area for the part of the column that rested on the scale. The cylinder-shaped column will use the formula for finding the area of a circle.

   | Shape | Formula |
   |---|---|
   | Circle | $A = \pi r^2$ |
   | Triangle | $A = \frac{1}{2} bh$ |
   | Rectangle | $A = bh$ |

5. Use the following formula to find how much pressure was exerted on each column.

   $$P = F / A$$

**Extension Activity**

Make a column from notebook paper that will support your textbook. Explore the effect of length on compression strength.

**LESSON PLAN THREE**

**Objective: Evaluating Materials in Terms of Heat Resistance Values**

In this activity the student will examine ways heat is transmitted. Students will use experimental methods to evaluate the effectiveness of heat blocking materials used by builders to maximize inside comfort.

**Focus Activity**

Discuss the three modes of heat transfer with the students. Have students look at a thermos and ask them to explain why a thermos can be used to keep a liquid cold or hot.

**What are some passive ways builders can maximize temperature-comfort inside structures?**

**Activity: Evaluating Materials in Terms of Heat Resistance Values**
Time: (2) class periods, 90-minute blocks

***Rationale:*** Architects consider energy saving techniques and materials when designing buildings. Consideration is given to the placement of windows, doors, and even to where a structure is located on a property. Older buildings that pre-date mechanical systems of heating and cooling relied chiefly on building considerations that maximized indoor comfort. Today insulation is one of the most efficient ways in which builders can protect the inside space of structures against fluctuations in outside temperatures. Thermal insulators are those materials that restrict the flow of heat. Heat is transferred through radiation, convection or conduction. Insulation provides for a passive restriction of heat by either of the above-mentioned methods. Insulators act as sieves, holding back some of the heat but not completely blocking all of it. The amount of heat that would pass through a material depends on the type of material. Three of the values used to evaluate the amount of heat allowed to flow through a material are the 'U' value, 'k' value, and the 'R' value. The 'U' value represents the amount of heat that flows through a square foot of material in one hour. The 'k' value is the conductivity value of a material. It reflects the amount of heat that can pass through one inch of thickness of a material. The 'R' value is the number of square feet it takes for one BTU to pass through a material. BTU is the amount of heat it takes to raise the temperature of one pound of water one degree Fahrenheit.

***Materials:*** In this activity students will be given materials to use as insulators. Each student group will be given the following material:

- (1) hot plate; a microwave can be used to warm the water
- (3) 100-150ml beakers labeled 1, 2, and 3
- (3) small thermometers
- time piece (watch or wall clock)
- (2) different types of insulation materials (newspaper, paper towel, wax paper, foil, etc.)
- data table

Baker’s mitten (for handling the heated beakers)

***Procedure:*** After students have received their materials, instruct them to place 100 ml of water in each of the three beakers. Allow each student group time to choose two different types of paper and cut them into one-foot squares. Instruct them to place all three beakers of water onto a hot plate or microwave. Warm the water until it is hot but not boiling. Carefully remove the beakers, one at a time, from the hot plate. Place one thermometer into each beaker and take the temperature. On your data table record the temperature of beakers 1, 2 and 3. Label this column initial temperature ($T_i$). Wrap beakers 1 and 2 in insulation (one type of insulation for each beaker). Remove the thermometers from each beaker and carefully place them on the table. Twist the insulation at the top so that it completely encloses the beaker. The third beaker will not be wrapped in any insulation—this will serve as your *control*. Let the three beakers set for 15 minutes and then unwrap beakers 1 and 2. Take a second temperature reading for all three beakers and record the temperature on your data table. Repeat this for two more times to make a total of four temperature recordings. Label your last temperature recording as the final temperature ($T_f$).

1. Find the temperature change for each sample using the following formula:
   Change in temperature = $T_i - T_f$
2. Which sample had the greatest ‘R’ value? Explain.
3. Which sample had the lowest ‘R’ value?

**Extension**: Students will make their own insulation cups using materials they select

## LESSON PLAN FOUR

### Objective

Students will research arches and domes in history. Their research should include information on how these structures are constructed. Students will make a two-dimensional arch and label its parts.

## LOAD BEARING CURVES: DOMES AND ARCHES (SCORING RUBRIC)

### Assignment

Each student is required to complete a research paper and present a three-dimensional model. Students may report on either domes or arches:

### *Domes*

1. Historical Perspective: Students will research the history of early domes and the purpose for building them. (20%)

2. Domes around the World: Students will research at least three different domes from different places in the world. (20%)
3. The Structure of Domes: Students will research the structure of domes to include information on structural framing and scientific principles governing the structure. (20%)

4. Make a three-dimensional model: Students will make a three-dimensional model and label its main parts. (20%)

5. Oral Presentation. (10%)

***Arches***

1. Historical Perspective: Students will research the history of early arches and the purpose for building them. (20%)

2. Arches around the World: Students will research at least three different arches from different places in the world. (20%)

3. The Structure of Arches: Students will research the structure of arches to include information on structural framing and scientific principles governing the structure. (20%)

4. Make a three-dimensional model: students will make a three-dimensional model and label its main parts. (20%)

5. Oral Presentation. (10%)

## Structure in Architecture
## Unit Scope
## Math

**The student will demonstrate an understanding of measurement concepts using metric and customary units. To demonstrate competency in this objective, the student must be able to:**

- Find the surface area of prisms using nets (two-dimensional models);
- Estimate answers and use formulas to solve application problems.
- Describe the resulting effects on volume when dimensions of a solid are changed proportionally; and
- Use proportional relationships in similar shapes to find missing measurements.

**The student will determine solution strategies and will analyze or solve problems. To demonstrate competency in this objective, the student will be able to:**

- Select and use appropriate forms of rational numbers to solve real-life problems, including those involving proportional relationships; and
- Use geometric concepts and properties to solve problems in fields such as art and architecture.

**The student will express or solve problems using mathematical representation. To demonstrate competency in this objective, the student will be able to:**

- Generate a different representation given one representation of data, such as a table, graph, equation, or verbal description; and
- Describe functional relationships for given problem situations and write equations to answer questions arising from the situations.

## Structure in Architecture
## Unit Scope
## Science

- The student is expected to measure the thermal and electrical conductivity of various materials and explain results.
- The student is expected to know the impact of energy transformation in everyday life.
- The student will be able to use scientific processes to conduct experiments using safe practices.
- The student is expected to investigate and demonstrate the movement of heat through solids, liquids, and gases by convection, conduction, and radiation.
- The student is expected to analyze the effects of heating and cooling processes in systems such as weather, living and mechanical.
- The student will be able to make conjectures about angles, lines, polygons, circles, and three-dimensional figures.

## APPENDIX: Tour of Houston Photos

P-1

The Julia Building was built in 1926. Designed by Cram and Ferguson, William Ward and Louis A Glover. It served as Houston's central library for 50 years.

P-2


Eugene Aubry of S.I. Morris Associates designed the Jesse H. Jones Building in 1975. This building serves as the central core of the Houston Public Library System.

P-3


The Brown Pavilion was designed by Ludig Mies van Rohe in 1954. it was attached to the Watkin building and became the new front to the Museum of Fine Arts (MFA).

P-4

University of St. Thomas - Jones and Strake halls are connected by a two - story breeze way. Architect Philip Johnson designed the halls in 1958 - 1959.
The Basilian fathers founded St. Thomas in 1947.

P-6

The Arches of Rice University

P-7

The Arches of Madison High

P-8

Arches of The University of Houston

P-9

St. Lukes Towers (Medical Center Houston)

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