Curriculum Units by Fellows of the Yale-New Haven Teachers Institute
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Geometry of Bridges

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by Michael Golia

Contents of Curriculum Unit

Opening Statement

As a teacher in the New Haven school system I have come to realize that students need to relate school with something in their life. Many of the students cross many bridges to get to school. The topic of bridges will help me introduce geometry into a real life application. The hands-on approach used in the building of a bridge project will develop student's academic and social skills. As students work on bridge construction in cooperative work groups they will apply not only mathematical principles but also social problem-solving strategies as they discover their "way" may not always be universally embraced. I have seen some students that get hooked on a project take it from its beginning to completion. This combination of geometry, working as a team, and having a project will help the students feel a sense of learning while having fun.

History of Bridges

"Since the first log fell across water, people have been fascinated with bridges and their power to bring together what had been separate. Bridges can evoke exhilaration, triumph, and fear, sometimes simultaneously. They figure substantially in the myths, legends, and allegories of many cultures, with each century adding to the strata of symbolism. Consider the associative power of the monumental Brooklyn Bridge, the crossing at Chappaquidick, or a covered bridge across a quiet creek in Vermont. Bridges span history. They have been built, burned, defended, crossed, and celebrated by kings, queens, monks, revolutionaries, and athletes, as well as by those of us who commute to work each day. Their story has been shaped by the elemental barrier of water and by the cities that grew up along the world's great waterways-imagine Paris, London, New York, or St. Petersburg without their signature bridges. Their sizes and silhouettes reflect the unfolding of mankind's knowledge of technology and building materials, as well as the influence of military conquest, religious belief, and economics.

The earliest primitive bridges, formed from beams, stones, and ropes, evolved into more complex structures fashioned by highly intuitive, often anonymous hands. The Roman domination of the known world was in part attributable to their particular genius for engineering, manifested in their singular masonry arch bridges, many of which still stand today. Lesser known in the West are the exceedingly fine and innovative crossings constructed by the Chinese. Construction methods employed in the sixth-century Anji Bridge in Zhaoxian predate any thing similar in the West by several hundred years. In the medieval world the construction of bridges fell to the religious orders and were funded by the faithful.

The Renaissance saw the rise of the inhabited bridge exemplified by the Ponte Vecchio in Florence and the Rialto Bridge in Venice-and the Palladian bride, which would not gain widespread currency until the eighteenth century, when Palladio's bridge designs were embraced by English landscape designers. The covered bridge, that most romantic of bridge types, is found throughout the world, but was particular popular in a rapidly expanding young America, where wood was plentiful and time was a premium.

The unassuming poetry of bridges reveals itself to those who would see them. Whether a simple crossing or an intricate labyrinth of steel, each of these structures has much to say about the extraordinary lives, effort, ingenuity and wonder that come together on a bridge."

Bridges

The definition of a bridge, according to Webster, is a structure carrying a pathway or roadway over a depression or obstacle. The word bridge can also be associated with people and how their life is sometimes linked to other people with bridges. In designing a lesson to fit the topic of "bridges" we have to look at the constituency of the students we are teaching. "At-risk" students often need a hook to motivate them. In this case, the actual building of a bridge will show the student a real item that they are building and how they can use math to accomplish this. Types of bridges that will be discussed:

- Arch Bridge
- Beam Bridge
- Cable-Stayed Bridge
- Cantilever Bridge
- Simple Truss
- Suspension Bridge

Arch Bridge-A type of bridge in which its weight is carried outward along the curve to supports at each end.

- Fixed Arch
- One-hinged Arch
- Two-hinged Arch
- Three-hinged Arch

Beam Bridge-A simple type of bridge composed of horizontal beams supported by vertical supports.

Cable-Stayed Bridge-A bridge in which the roadway deck is suspended from cables anchored to one or more towers.

Cantilever Bridge-A projecting structure supported only at one end, much like a shelf bracket or a diving board.

Simple Truss-A triangulated structure based on the theory that all loads can be carried by simple tension and compression members whose axis is the line of force and all forces may be resolved into stable static equilibrium at points where triangulated lines of force intersect.

Suspension Bridge-A bridge in which the roadway is hung from strong cables that pass over two towers.

School Description

I teach at an alternative high school that receives most of its students from the largest comprehensive high school in New Haven. The students have a multitude of problems (i.e., absenteeism, lack of academic credit and discipline issues). Our school is about teaching and learning in a small environment, providing team-taught courses, and creating an environment where it is hard for students to fall through the cracks. The program promotes education through academic and personal development change. The focus of the school is to have the students make up credit. Students earn credit in four course subjects: English, math, science and social studies/history. They earn credit by the semester. Most classes are taught in 90-minute blocks to help meet the variety of learning styles in the classroom. We offer seven credits per academic year some students return to the main high school to graduate with their classmates; others complete their credits at our program

Team-taught classes promote teamwork, problem solving and active learning, with an emphasis on writing and literacy. Teachers are willing to work with students and their families and to be advocates for the student, when necessary.

At Risk Students

The student population of New Haven is a diverse group, some of which can be identified as "at risk students." The loose definition of these adolescents is students in danger of failing to complete their education with the skills necessary to survive in a modern technological society. Statistics reveal that urban areas have many students who exhibit at-risk characteristics such as the following: low self-esteem, male, minority, non-native English speaking, divorced families, transients, and inner city students. All the problems that accompany these students are too numerous to mention but among them are: high dropout rate, high rates of drug use, low grades etc.. Effective instruction for at-risk students means challenging assignments. The effective program stresses high expectation, and academic focus, continuous monitoring of progress, and strong parental involvement. Effective programs prevent problems by being flexible and adaptive to student needs rather than merely providing remedial learning. Effective teachers have high expectations and use a variety of instructional and motivational strategies. The teacher shows a sincere interest in the students' lives. The overall theme of this unit gives the students the necessary skills to find information on bridges and to use the information to build their own bridge.

Geometry

Incorporating geometry in with bridges serves two purposes: the study of shapes and symmetry and the function of design. The shapes of geometry: squares, triangles, rectangles, and other geometric shapes can work in the designing of a bridge. The function or use of these geometric designs will show the students that geometry is important. Students working with different three-dimensional shapes will explore how and where the students can use these shapes in their bridges. The shapes can be tested to see which designs are the strongest how much weight can they hold or what pressure can be applied to see the breaking point. This will help the students in their design. Also the students need to explore how they can build a strong bridge with the use of a minimum of material. Sometimes the availability of materials can dictate the design of the bridge. The strength of the bridge is not necessarily determined by the bulk of material. In geometry the students will need to understand certain geometric terms:

1. Lines-A line extends forever in two directions
Types of lines:
    a. A ray extends forever in one direction
    b. A line segment is a line between two points
    c. Parallel lines are lines that do not intersect
    d. Perpendicular lines are two lines that intersect at a right angle
2. Angles-An angle consists of two rays that meet at the same point, which is called the vertex.
Types of angles:
    a. Acute angle-measures between 0° and 90°
    b. Right angle-measures 90°
    c. Obtuse angle measures between 90°and 180°
    d. Straight angle measures 180°
3. Symmetry:
Symmetry is when a figure can be divided by a line and both resulting halves are equal-mirror images of the other.
4. Triangles-A polygon with three sides
Types of triangles:
    a. Scalene triangle-all sides have different lengths
    b. Isosceles triangle-at least two sides have the same length
    c. Equilateral triangle-all three sides have the same length
Triangles identified by their angles
    a. Acute triangle has three angles that are acute
    b. Obtuse triangle has one angle that is obtuse
    c. Right triangle has one angle that is a right angle
5. Quadrilaterals-A polygon with four sides
Types of quadrilaterals
    a. Parallelogram is a quadrilateral with opposite sides parallel
    b. Rectangle is a quadrilateral with four right angles
    c. Square is a rectangle with sides of equal lengths
    d. Rhombus is a parallelogram with sides of equal length
    e. Trapezoid is a quadrilateral with only one pair of parallel sides
        1. A trapezoid is isosceles if its non parallel sides have the same length

6. Regular polygons have sides that are the same length and angles that have the same measurement.

7. Polyhedron-is a solid that is bounded by polygons, which are called faces. The segments where the faces meet are edges, and the points where the edges meet are vertices

Types of polyhedrons and solids:

- a. Prisms
- b. Pyramids
- c. Sphere
- d. Cylinder
- e. Cone

Some terms in physics will also need to be discussed:

Compression, tension, live load, and dead load.

Research On The Internet

The students will use the computer to research a specific bridge, the types of bridges, or design a bridge on the computer. The power of the computer will be demonstrated to the students so that they can realize that the computer is more than a game machine. With the use of the computer the student will gain confidence, with less frustration. The World Wide Web (www) is the new place in the modern age to attain information. In our lessons we will use the Web as one source of information. To navigate around the web, we needed a browser. The browser we will use is called Netscape Navigator. In order to become familiar with this tool I will discuss the necessary jargon for the system.

The Netscape Navigator is an easy program to use. With this tool one can read text and view pictures of bridges on pages known as web pages. You can use the scroll bar on the left side of the page to review the screen, or use page up and page down to move up and down on the page. To move around the web, you can use the hyper link, choose one of your previously defined bookmarks, or type a new URL into the location box on top of the screen. The net will be used in the first assignment to look up different types of bridges.

Materials Used For A Bridge

The first bridge was probably built of a log across a stream. This bridge was used to cross a body of water without getting wet. Pedestrian bridges were probably the first bridges. As people explored and move across the country on wagons structures were needed to cross the streams and rivers. Structures and how they are built rely on what materials are available where they are built. Wood, stone, cast iron, steel, and concrete can be used in building a bridge. The use of materials has changed throughout history; the factors for this change are the climate of the area (will the material stand up in the climate), the culture (does the bridge need to last a long time or is it temporary), and finally the change in technology (new materials being developed). The students will explore how materials react to different conditions. By manipulating different building materials the student will see each reaction and will be able to tell more about certain materials. The student will decide what material will be best for their bridge.

Mathematical Scaling

The necessity to show the students scaling and how it is used will be an integral part of the modeling making process. To design a bridge the students will have to draw a plan of the bridge. The students will have to use a scale (ratio) of the size of the bridge they are building and the size of the final bridge. To get the best results for the bridges you will need to set certain guide lines. The size of the model will have certain restrictions (length, width and height). This will force the students to work within certain parameters. You will need to give the student information about how wide is a lane of traffic, how wide is the sidewalk, what clearance is necessary for traffic to pass under. This information and much more information is necessary for the student to clearly understand what is expected of them.

Field Trips

Field trips to a bridge site and to a model fabricator will be necessary to show the student what is entailed in building a bridge. The trip to a site will show the students the real size of a bridge. The trip to the model fabricator will show the student what is necessary to build a model to scale, what materials will best suit the model builder and how they can simulate the fabrication of the bridge.

Conclusion

This curriculum unit will give the students the opportunity to use the math skills that they are developing as they incorporate them into this project. The wide reading base that the student will be accountable for should spark their interest in many more projects. The final project of building a model will help the students understand that there is a correlation between math and the real world. Hands on projects are a very effective way to reinforce mathematical concepts. I believe that the students will enjoy this unit on bridges and they will learn not only how to build something but how to work with other students to achieve an end.

Lesson Plan I

Objective:

Student will:

1. Understand that there are different types of bridges.

2. What is the purpose of the bridge (vehicular or pedestrian).

3. Why was the bridge built.

Materials: The use of computers, and reference material from the library. Butcher block paper and some markers.

Procedures: Students will work in pairs. The types of bridges will be introduced before the students do this research. Students will research a bridge and will answer questions about the bridge. Who, What Where, Why, When and sometimes how. Students will draw this bridge on white butcher-block paper, using a scale to draw the bridge.

Homework: The students will describe a bridge that is close to their home, an answer: why was it built, what was it built of, when was it built, why do you think it was built there, and how do you think it was built. Included in their homework will be a sketch of the bridge.

WORK SHEET FOR LESSON PLAN I

(chart available in print form)

Lesson Plan II

Objective: Students will learn how to manipulate a piece of paper to hold weight between a span.

Materials Needed: Two pieces of 8 ½ by 11-inch paper, weights and two books

approximately 1in. thick.

Procedure: Have students work in pairs, make them record what they have tried and

what has happened. They will also have to draw what they are doing so they will get use to drawing as well as writing. As they try each experiment their success or failure will help them think differently. The reason for this lesson is to show the student that by changing the materials into a different form it will hold up weight.

Check for understanding: Have each group report on what they have tried. They will need to tell why something has worked or not. The students will see that in some cases they have tried the same procedures, and in other cases the students will be the only ones that have tried it. There should be some discussion on each of the student's reports. This will help the students try to understand why each of the experiments works.

Lesson Plan III

Objective: The student will design and build a model of a bridge tower. The criteria of the tower use the materials and design guidelines listed below. Materials:

- Coffee can
- 75 uncooked spaghetti noodles
- 2m (6.5ft.) masking tape
- Standard set of weights (fishing sinkers work well)
- 6 strips of corrugated cardboard:
  - 8cm x 30 cm (3in x 12in)
  - 8cm x 50 cm (3in x 20in)
  - 8cm x 80 cm (3in x 31in)
  - 8cm x 100 cm (3in x 39)
  - 8cm x 120 cm (3in x 47)
  - 8cm x 150 cm (3in x 59)

Tower Criteria

The structure must

- Balance the longest road possible
- Support the most weight possible
- Prevent twist and turns

Design Guidelines:

- The base of the coffee can must be 30 cm (about one foot) above the floor or your desktop.
- The base of the structure should be no wider than the diameter of the can.
- The spaghetti can be cut to any length.
- The spaghetti can be taped at the top and the bottom only.
- The coffee can must be positioned with the open end facing up so you can add weights to it.

Procedure

1. First, look at your material and think about how you will design your bridge to meet the challenge. Draw your design on a separate sheet of paper.
2. Using the spaghetti noodles and tape, build a structure that will support the coffee can. Record the number of noodles used.
3. After you have completed the structure, find the maximum length of cardboard road that can balance on top of the coffee can. Record the road length.
4. Next, find the maximum amount of weight the structure can support. Remove the road (cardboard) and slowly add the weights inside the can. Record the maximum weight the structure can support before collapsing. Stop adding weights when it starts to wobble.

(chart available in print form)

5. Retest the road with the maximum amount of weight in the can and record your results. Does the length of the road, that the bridge is able to carry, increase or decrease when there is weight in the can? Explain.
6. On a separate sheet of paper, sketch your design and point out its strengths and weaknesses. After comparing your design with others in your class, write down two things you would do to improve your bridge.

Bibliography

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Day, Christopher, *Places of the Soul, Architecture and Environmental Design As a Healing Art* , Harper Collins, Hammersmith, London, 1995. How architectural environments make an impact.

Hawkes, Higel, *Structures: the Way Things Are Built* , Macmillan Publishing Co., New York, 1993.

Man made structures and how they are made.

Student Reading List

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Kaner, Etta, *Bridges* , Kids Can Press, 1997. A guide to hand-on building of models.

Macaulay, David, *Building Big* , Houghton Mifflin Co. 2000. Wonders of the construction world: dams, domes, skyscrapers, tunnels and bridges.

Petroski, Henry, *Engineers of Dreams: Great Bridge Builders and the Spanning of America* , Vintage Books, 1996. A history of five engineers who have built bridges.

Teacher Reading List

Dupre, Judith, *Bridges: A History of the World's Most Famous and Important Spans* , Black Dog & Leventhal Publishers, New York, 1997. A chronological collection of forty-five bridges

Gottemoeller, Frederick *Bridgescape: The Art of Designing Bridges* , John Wiley & Sons, 1998 This book defines line, form and placement in a site.

Links

Bridges: Reaching Out http://www.discovery.com/stones/techonology/building/bridges.html

Technology & Bridges Design http:projects.edtech.sandi.net/pbmiddle/bridges

Building minds: Span-It Game http:lsb.sur.edu/projects/structures/resources.html

West Point Bridge Designer http:bridgecontest.usma.edu

Bridges: Bridge Project Menu http://cl.k12.md.us/bridges/bridgept.htm

Truss Bridge Laboratory http://www.ce.ufl.edu/activities/trusslab/trussndy.html

The Bridge Challenge http://www.pbs.org/wgbh/buildingbig/bridge/challenge/index.html

NOVA Online Bridge Activity http://www.pbs.org/wgbh/nova/bridge/build.html