

Pittsburgh Bridges: Building for the Future

*Tammy Rullo
Pittsburgh Gifted Center*

Overview

Rationale

Objectives

Strategies

Classroom Activities

Annotated Bibliography/Resources

Appendices-Standards

Overview

Pittsburgh over the past few decades has morphed from a city with the reputation of being drab, smoky, and industrial to a beautiful and livable city architecturally. With the celebration of the city's 250th birthday this renaissance is worth celebrating as well. The purpose of this unit is to integrate the historical and functional value of Pittsburgh's bridges with elementary math.

Rationale

The rationale for choosing this particular unit is multifaceted. Currently, I am a third grade math teacher at the Pittsburgh Gifted Center. Each year our team designs curricular units around a particular theme. Our theme this year is the celebration of Pittsburgh's 250th birthday. We strive at our school to try and incorporate as many cross-curricular activities within our content area as possible. It is important for my students to understand that no matter what profession they choose later in life, they will have to have a broad base of skills for the job. Although the students are young, because they are gifted learners we focus on the strengths of the students rather than the weaknesses. Most of the students have a grasp of math knowledge well beyond grade level. Therefore, I design lessons so that there is real world applicability. As with each unit, the lessons are chosen with higher level thinking skills in mind. I compiled this unit to introduce bridge design and engineering because it was an excellent reinforcement of design, function, and strength of geometric forms. This unit provides a mix of team work, technology, and hands-on lessons to allow the students a broad variety of ways to explore the bridges in our city.

Pittsburgh has more bridges than any other city in the world, depending on how one defines a bridge, and without them, the face of the city would be completely changed. Over the past several decades, our city has metamorphosed from an industrial city in need of a make-over to one of the most beautiful and livable cities in the US. Millions of years ago Pittsburgh was a flat sea floor and over all this time, erosion carved the surface into an area where rivers and tributaries flow. The terrain of Allegheny County, with its steep hills and low valleys require at some reports over 2,000 bridges of 8 feet span or greater. According to a recent study, 446 of those bridges belong to the city of Pittsburgh.

Even the most primitive humans had to have constructed simple bridges to move from one place to the next in search of food. Fallen trees and vines were used to bridge gaps in the topography. The Romans forged great architectural achievements with their aqueducts, arch bridges, and the invention of the cofferdam. Their construction accomplishments forged the way for later bridge designs from bridges with houses on them to the marvelous suspension and cantilever bridges seen today. Most people take these fixtures for granted. Without the various forms of bridges found in our city, Pittsburgh would not have expanded and thrived as it has.

The mills and mines of Pittsburgh brought many immigrants to our city. Residential areas developed based on the ethnic groups settled in the area. In order to accommodate the growing work force and keep business vital in Pittsburgh the city's expansion included newer and more bridges. This unit not only focuses on the mathematics involved in bridge building but on the aesthetics, form, and function of the bridges found in Pittsburgh. The primary styles of bridges found in this area are the girder, truss, arch, cable-stayed, rigid frame, and suspension bridges. In order for students to understand these bridge forms, some background research needs to be developed on the styles. The matsuo bridge website listed in my sources is a great visual reference on these structures. Here is a brief synopsis of each:

Girder bridges

The common girder bridge is a bridge built of girders on bridge abutments. An early example is a log across a stream.

Truss bridges

Truss bridges are composed of connected elements. They have a solid deck and a lattice of pin-jointed girders for the sides. Early truss bridges were made of wood, and wood with iron tensile rods. Modern truss bridges are made completely of metals such as wrought iron and steel or sometimes of reinforced concrete.

Arch bridge

Arch bridges are arch-shaped and have abutments at each end.

Cable-stayed bridges

Like suspension bridges, cable-stayed bridges are held up by cables. However, in a cable-stayed bridge, less cable is required and the towers holding the cables are proportionately shorter.

Rigid frame bridge

In a rigid frame bridge the piers and girders are fused to create one solid structure.

Suspension bridges

Suspension bridges are suspended from cables. The earliest suspension bridges were made of ropes or vines covered with pieces of bamboo. In today's suspension bridges, the cables hang from towers that are attached to cofferdams.

After the students explore the site, pictures of actual Pittsburgh bridges can be shown and a discussion on the form and function of each bridge can take place.

Because I teach a class of gifted students, the students have mastered many of the basic grade level math skills and need a more challenging perspective on math concepts. One lesson involves geometry as it relates to strength in bridge design and function. The basics for the geometry lesson are found on the website thinkingfountain.org. It involves using soap bubbles to explore three-dimensional shapes. When examining geometric shapes used in bridge design and then looking at the area of those same shapes by filling them with soap bubbles, I am able to help the students to visualize on a small scale which shapes can handle the most resistance. After looking at the resistance of the bridges, students can use the interactive bridge building website learn4good.com. It allows students to simulate bridge building and then test the strength of their design. We work on developing leadership and team building skills as well in each class so that these process skills are integrated into this unit, too. I designed this unit to focus primarily on math, but have incorporated other lessons to broaden the students' perspective. Therefore, the purpose of this unit is to integrate a cross-curricular study of bridges with social studies, math, and art.

Objectives

In this unit students will explore the basic design and structure of bridges in Pittsburgh as well as a few in other parts of the country as a comparative study. Basic 2-dimensional and 3-dimensional geometric shapes will be explored and discussed based on the strength and durability of these shapes. Not only will the functionality of the bridges be talked about, but the aesthetic quality of the bridges will be incorporated as well. Students will understand the social and historical ramifications of the beautification of Pittsburgh. After

those aspects are explored a team of students will begin the task of constructing a bridge using math skills based on the state standards.

Strategies

Various strategies will be used to teach this lesson. The first will be to get the students interested in the bridges that are throughout the city. They cross them almost every day, and the hope is to develop a real interest in the beautiful architecture and more importantly the bridges in our city. The first lesson will be simply to collect facts and take an in-depth look at the bridges in our city. This will be accomplished by viewing a PowerPoint presentation on the bridges, gathering information on the computer, and teacher lecture. Higher level thinking questions will be posed to enrich the lesson. Hands on student centered activities will be used to reinforce the math techniques and enhance the understanding of the function and durability of the bridge designs. A culminating team project of designing and building a bridge will be completed. These activities will involve geometry, measurement, design, construction, and accounting skills. This list of classroom activities is meant to provide various math experiences while exploring the bridges of Pittsburgh.

Classroom Activities

We will look at pictures of the bridges, their names, and what their function is to the city. A brief history about the bridges will be given as well. Students will discuss the beauty of these city connectors and share any other stories they have about the bridges. This is to pique their interest in the bridges in our city. Next, students will complete a lesson on geometry to introduce them to the durability and function of the geometric shapes used in construction. By creating 3-dimensional shapes using toothpicks and clay and dipping them into soap bubbles students will be able to develop a basic understanding of the structural durability of various 2-dimensional and 3-dimensional shapes. The various construction materials used in bridge building will be introduced and the historical importance of steel to our city will be included. A mini lesson on measurement should be included and importance of exact specs be incorporated to the function and design of construction. After that, students will be divided into teams. Team building strategies will be reinforced and roles will be given to each team member (i.e. engineer, contractor, etc.) Basic accounting skills using spreadsheets will be initiated so students will be able to keep track of the money they will use for construction. It will be important for the teams to plan for the materials and stay within budget. Each team will receive an amount of “cash or credit” with which to purchase materials for their bridges that are provided by the teacher. A bridge will be designed by the team based on its purpose to the city, and a list of materials needed for the construction should be developed. The students will purchase tools and materials needed for their bridge construction. An account record of the

purchase will be kept. A test of strength will be given using some type of weighted material (such as science weights or matchbox cars) and as a whole class students will talk about the aesthetic quality of the design. At this point, difficulties with the project can be discussed with the class as well as enlightened moments while developing the plans and during construction. Higher level thinking questions should be posed based on this discussion. When the bridge building is complete, students will assess the effectiveness of their project using a self-evaluative rubric and peer rubric. The teacher will also assess the math skills developed and the team building skills using a rubric.

Lesson Plans

Lesson 1

Objectives

The very first lesson will be an introduction to bridge building. It will primarily be an overview of the unit, a review of vocabulary, and an introduction to the types of bridges found in the city of Pittsburgh. The objectives of this lesson are:

- To review and understand the purpose of the unit
- To compare and contrast the types of bridges found in the city of Pittsburgh
- Discuss and analyze the form and function of the various bridges found in Pittsburgh

Vocabulary Words

Form

Function

Truss Bridge

Suspension Bridge

Arch Bridge

Pipe Bridge

Cable-stay Bridge

Materials Needed

Pictures of bridges or PowerPoint presentation of different types of bridges

Procedure

Teacher will begin lesson by asking students to define the word bridge. After a discussion, teacher will clarify that there are many types of bridges, especially in the city of

Pittsburgh. A history of bridges will be presented through a PowerPoint presentation along with pictures of bridges in our city. Along with this, a photographic presentation of a bridge under construction will be shown along with an explanation of exactly what is being done during the phases of construction. The terms form and function will be defined and the students will learn to recognize form, function, and construction materials throughout this process. A sheet defining bridge types will be used to help the students follow the various designs. A casual artistic evaluation of each bridge in the presentation will be made to help the students to formulate opinions on various designs and for them to recognize that while safety is the first priority, the city wants the bridge to enhance the city and not obstruct the view.

Lesson 2

Objectives

This lesson centers on geometric shapes and the scientific process to help students understand why certain geometric shapes (primarily the triangular prism/pyramid and the arch) are used most often in bridge design. The objectives are:

- To use models to illustrate a concept and compare them
- To analyze characteristics and properties of two- and three-dimensional geometric shapes and demonstrate understanding of geometric relationships
- To identify three-dimensional figures
- To use evidence such as observations or experimental results to support inferences about a relationship
- To develop descriptions, explanations, predictions, and models using evidence

Vocabulary Words

Prism

Cube

Sphere

Rectangular prism

Pyramid

Scientific Observation

Materials Needed

Paper Towels for clean-up

Soap bubble (blowing bubbles kind)

Toothpicks

Modeling clay (not play-doh or air hardening clay)

Plastic container large enough for completed geometric shapes to fit in

Teacher made scientific observation sheet
Pencils

Procedure

The teacher will explain that the purpose for the lesson is to determine which shapes are structurally strongest to be used in bridge design. Next, the students will recall by comparing and contrasting two-dimensional and three-dimensional shapes. Students can then name various three-dimensional shapes. Teacher should have some type of visual aid such as a picture or a student can even draw the shape on the board just to reinforce the concept. Teacher will then divide the class into teams of 2-4 students and emphasize team building rules (be responsible, cooperate, be helpful, be a good listener, etc.). Teacher will explain that teams are going to build small three dimensional shapes using toothpicks as lines and small balls of clay as the vertices. Next, teacher will pass out scientific process sheets, discuss scientific inquiry, and clarify the lesson procedure. Each team will choose 3 different three dimensional shapes and draw them on the process sheet. Students will then make a prediction as to what will happen after they construct each shape and totally immerse them into the container of soap bubbles. After the construction and immersion, students will write their observation and analyze the strength of the shape. Students are always amazed to find that all the shapes except for the cube and the rectangular prism have a volume that is totally filled with other smaller geometric shapes formed of bubbles. The cube and the rectangular prism (if they hold up during the immersion) are easier to spot as the weaker shapes because only the area becomes coated with the bubbles. The triangular prism has a volume completely filled with other triangular prisms. Even when a small amount of pressure is placed at the top point of the shape, the bubbles don't break as quickly as they do on the other shapes. The teacher can then have students discuss their findings and ask open-ended questions steering the students to deduce that the triangular prism is used most often in bridge design because it is structurally the strongest shape. Teacher can then tie this into the previous lesson on truss bridges.

Team Members: _____

1. Sketch 3-dimentional shape you are planning to construct and name the shape.

What do you predict will happen to the shape after it is dipped into the bubbles?

What was your observation after dipping the shape into the bubbles?

What is your analysis of the strength of this shape based on your observation? Explain.

Lesson 3
Objectives

This activity will clarify the basic notion of supply and demand. This will be important for the students to understand because when they later build their bridges, each team will be given a different amount of cash to spend. Students need to understand that they are not being treated unfairly. In our free market society not all businesses have the same amount of capital to invest or spend. This will also help to produce a variety of bridge designs in the classroom. The objectives for this lesson are:

- To define scarcity and limited resources
- To identify and define wants of different people
- To explain how self-interest influences choice
- To explain why people work to get goods and service

Vocabulary

Scarcity
Supply
Demand
Free Market

Materials Needed

3 lollipops
Teacher made organizational chart
Scratch paper
Pencils

Procedure

Before the lesson begins, the teacher will divide students into teams of 2-3 students. Reinforcement of team building rules will be needed. Teacher will ask students to define scarcity using open-ended questioning to come up with an answer. Teacher will then explain that he/she has lollipops and ask who would like one. (Usually everyone raises their hands.) Then the teacher will explain that lollipops are scarce in the classroom that day. There are only three to give to students and the teacher will explain that they can't be divided (or broken). At this point the terms supply and demand can be defined since the demand for the lollipops is high and the supply is low. During this dialogue the term free market society can be tied into that idea and coupled in with the basic notion of how businesses in our society function.

Each team should be given a sheet of paper. Clarify that they will have to come up with as many ways as possible to decide who should get the lollipops. Explain that they are not evaluating at that point whether the method is a good technique or not; that assessment will come later. (Therefore if someone suggests fighting for them or stealing them, let them keep that answer.) Facilitate the teams as they are working to make sure they stay focused or help them be as creative as possible with the ideas. After teams are finished compiling the lists, the teacher will either hand-out teacher made scarcity chart or create one on the board. Since I teach third graders, I feel this part of the lesson is best done as a whole group because the concept is new. That way I can help guide the discussion in the direction I feel is necessary. This chart will help the students organize their thoughts on their methods of distribution. . If the students are older or have prior knowledge of the concept, then they can remain in their groups to discuss the validity of each idea as a team. Teacher will lead the discussion by filling out the chart with the

students. In the first column write down all of the different distribution ideas that the students developed. Next, make a checklist in the top row. This checklist should include the following questions: Can it be done?, Is it fair?, Does anyone get hurt?, Can it be done in a timely manner?, and any other question you think feasible to the situation. As students analyze each idea they have chosen, discuss the pros and cons of each selection. Guide the discussion to relate it to the amount of money they will receive for the bridge building. Have the students decide based on the results of the chart which way would be best to distribute the lollipops and follow through. I would choose to only give out the three lollipops just to reinforce the concept of supply and demand.

Lesson 4

Objectives

This lesson will begin the introduction to building the bridges. The actual construction will take several days or weeks depending on the time allotted in an individual classroom. Since I only see my classes one day a week, I intend to use four weeks, to complete this part of the lesson. The objectives for this lesson are:

- To use geometric shapes to solve problems
- To work as a team
- To use the creative thinking process
- To understand shapes and their properties and apply them to a model
- To synthesize previous information to construct a bridge

Vocabulary

Any materials chosen to build bridges such as spackle will be included.

Materials Needed

Spaghetti
Spackle
Mini/regular/ and large Popsicle sticks
Plastic cylinders
Rulers
Wire
Duct Tape
Paper
Pencils
Lego
Glue

Procedure

The teacher will be dividing the students into groups of 2-4 students for the actual construction. Previous groups may be used or new groups developed based on the classroom. Each team will be given a different amount of cash (credit) for shopping for bridge building materials. In my class increments of \$2,000,000, \$1,000,000, \$700,000 and \$300,000 will be distributed. A price list for the materials will be handed out to the students with that so they know in advance the prices for materials and what their budget will be. This should allow for a variety of classroom bridge designs. Students will then decide on the form and the function of their bridges. An exploration of books and web photos should help them with the design. After a sketch is completed, the teacher will meet with each team individually to discuss the design and its structural validity. Students must create a list of building supplies, calculate the cost based on the price list, and deduct the cost from their total store credit and confirm their calculations with the teacher before their purchase. They can continue to buy supplies as needed, but there will be a no returns policy. After construction, the bridges will be tested for structural soundness using small scientific weights. However, so as not to ruin the constructed design, weights will only be used so no damage to the bridge occurs. A rubric will be used to score the designs.

Rubrics:

	5 Excellent Progress	4 Very Good Progress	3 Good Progress	2 Basic Progress	1 Progress Needed	Score
Research and Gather Information	Collects a great deal of information that relates to topic.	Collects some information that relates to topic.	Collects some basic information-most relates to topic.	Collects very little information-some relates to topic.	Does not collect any information that relates to topic.	
Cooperative Learning	<u>Consistently</u> -Works effectively with others -Shares ideas	<u>Frequently</u> -Works effectively with others - Shares ideas	<u>Occasionally</u> -Works effectively with others -Shares ideas	<u>Minimally</u> -Works effectively with others -Shares ideas	<u>Rarely or Never</u> -Words effectively with others -Shares ideas	
Fulfill Team Role Duties	Performs all duties of assigned or chosen team role	Performs nearly all duties of assigned or chosen team role.	Performs some duties of assigned or chosen team role.	Performs very few duties of assigned or chosen team role.	Does not perform any duties of assigned or chosen team role.	

Makes Fair Decisions	Consistently makes insightful judgments or decisions.	Usually makes insightful judgments or decisions.	Occasionally makes insightful judgments or decisions.	Minimally judges decisions	Rarely or Never judges decisions.	
Production	Individual has exceeded expectations of assignment.	Individual has successfully produced the intended assignment.	Individual has satisfactorily produced the intended assignment.	Individual produced assignment with limited understanding of topic.	Individual has not produced the intended assignment.	
Presentation	Individual exceeded expectations and showed consistent content knowledge.	Individual successfully presented information showing frequent content knowledge.	Individual presented information showing occasional content knowledge.	Individual presented information with a limited understanding of project or topic.	Individual did not successfully present the information and showed no understanding of project.	

Teacher Evaluation Form

Student Name _____

Presentation Date _____

Student Role _____

Final Product _____

Comments:

	5 Excellent Progress	4 Very Good Progress	3 Good Progress	2 Basic Progress	1 Progress Needed	Score
Research and Gather Information	Collects a great deal of information that relates to topic.	Collects some information that relates to topic.	Collects some basic information-most relates to topic.	Collects very little information-some relates to topic.	Does not collect any information that relates to topic.	
Cooperative Learning	<u>Consistently</u> -Works effectively with others -Shares ideas	<u>Frequently</u> -Works effectively with others - Shares ideas	<u>Occasionally</u> -Works effectively with others -Shares ideas	<u>Minimally</u> -Works effectively with others -Shares ideas	<u>Rarely or Never</u> -Works effectively with others -Shares ideas	
	Performs all	Performs nearly	Performs some	Performs very	Does not perform any	

Fulfill Team Role Duties	duties of assigned or chosen team role	all duties of assigned or chosen team role.	duties of assigned or chosen team role.	few duties of assigned or chosen team role.	duties of assigned or chosen team role.	
Makes Fair Decisions	Consistently makes insightful judgments or decisions.	Usually makes insightful judgments or decisions.	Occasionally makes insightful judgments or decisions.	Minimally judges decisions	Rarely or Never judges decisions.	

Self Evaluation

Your Name _____

Your Role _____

Final Project _____

Comments:

	5 Excellent Progress	4 Very Good Progress	3 Good Progress	2 Basic Progress	1 Progress Needed	Score
Research and Gather Information	Collects a great deal of information that relates to topic.	Collects some information that relates to topic.	Collects some basic information-most relates to topic.	Collects very little information-some relates to topic.	Does not collect any information that relates to topic.	
Cooperative Learning	<u>Consistently</u> -Works effectively with others -Shares ideas	<u>Frequently</u> -Works effectively with others - Shares ideas	<u>Occasionally</u> -Works effectively with others -Shares ideas	<u>Minimally</u> -Works effectively with others -Shares ideas	<u>Rarely or Never</u> -Words effectively with others -Shares ideas	
Fulfill Team Role Duties	Performs all duties of assigned or chosen team role	Performs nearly all duties of assigned or chosen team role.	Performs some duties of assigned or chosen team role.	Performs very few duties of assigned or chosen team role.	Does not perform any duties of assigned or chosen team role.	
Makes Fair Decisions	Consistently makes insightful judgments or decisions.	Usually makes insightful judgments or decisions.	Occasionally makes insightful judgments or decisions.	Minimally judges decisions	Rarely or Never judges decisions.	

--	--	--	--	--	--	--

Peer Evaluation

Your Name _____

Teammate's Name _____

Teammate's Role _____

Final Project _____

Comments:

Annotated Bibliography/Resources

Reading Selection for Students:

Doherty, Craig A. The Golden Gate Bridge (Building America). Blackbirch Press, 2007.
This is a readable account of the description of the building of the Golden Gate Bridge. It includes beautiful, historical photos of the actual construction.

Zaunders Bo. The Great Bridge-Building Contest. Harry N. Abrams, 2004.
This book is a tribute to Lemuel Chenoweth who was a cabinet maker. He created The design for a covered bridge built in 1852 pivotal to the Civil War.

Johmann, Carol A. Bridges: Amazing Structure to Design, Build, and Test _____
(Kaleidoscope Kids). Williamson Publishing Company, 1999.

A mix of science, history, and technical instruction on bridge building.

PBS Online, "Big Bridges." Accessed: June 15, 2009. Copyright: 2000-2001.

<http://www.pbs.org/wgbh/buildingbig/bridge/index.html>

A great PBS website. Students can build virtual bridges, explore photographs, or research architects and engineers.

Learn 4 Good, "Games". Accessed: June 3, 2009 Copyright: 2003-2008.

http://www.learn4good.com/games/simulation/build_bridge_across_canyon.htm

This is a great website for kids to reinforce bridge building techniques. They can build virtual bridges with varying degrees of difficulty and test the strength of the created bridge.

Reading Selection for Teachers:

Pollard, Jeanne. Building Toothpick Bridges (Math Projects: Grades 5-8). Dale Seymore Publications, 1985.

Fictional account of a company that has to build a bridge that beats budget and bears a required load. A great tie in to final project.

Cleary, Richard. "Edgar J. Kaufmann, Frank Lloyd Wright and the 'Pittsburgh Point Park Coney Island in Automobile Scale'". *The Journal of the Society of Architectural Historians*, Vol. 52, No. 2 (June, 1993) pp. 139-158.

Important historical information to the city of Pittsburgh. Frank Lloyd Wright created a futuristic design of the point. It explores Wright, his design for the Point, and why it was overwhelmingly rejected.

Dreicer, Gregory K. "Building Myths: The 'Evolution' from Wood to Iron in the Construction of Bridges and Nations". *Perspecta*, Vol. 31, Reading Structures (2000), pp. 130-140.

Looks at the truss bridge design and its evolution from wood to iron.

"The Topic: Bridge Building." Accessed: April 15, 2009. Copyright: November 1999. Continuously modified.

<http://www.42explore.com/bridge.htm>

This is a clearing house for bridge building sites for kids. It offers engineering perspectives, vocabulary, photographs of types of bridges.

Matsuo Bridge Company, "The Basic Bridge Types." Accessed: May 19, 2009. Copyright: 1999.

<http://www.matsuo-bridge.co.jp/english/bridges/index.shtm>

This site offers definitions for bridge terminology, in-depth construction information on the types, and basic sketches of form and function.

Science Museum of Minnesota, "Thinking Fountain: Bubble Geometry." Accessed: March 20, 2009. Copyright: 1995-2004.

<http://www.thinkingfountain.org/b/bubblegeometry/bubblegeometry.html>

This site shows a few photographs of completed bubble geometry shapes.

Wikipedia, "Bridge". Accessed: June 3, 2009. Continuously modified.

<http://en.wikipedia.org/wiki/Bridge>

Provides basic information on bridges and beautiful photographs of types of bridges.

Standards:

6.2. Markets and the Functions of Governments Computation and

2.2. Estimation

Basic functions (+, -, ×, ÷)

Reasonableness of answers

Calculators

Computing and comparing measurements

2.3. Measurement and Estimation

Types of measurement (e.g., length, time)

Units and tools of measurement

2.9. Geometry

Shapes and their properties

Using geometric principles to solve problems

2.5. Mathematical Problem Solving and Communication

Problem solving strategies

Representing problems in various ways

Interpreting results

2.4. Mathematical Reasoning and Connections

Using inductive and deductive reasoning

Validating arguments (e.g., if...then statements, proofs)

3.6. Technology Education

A. Biotechnology

B. Information Technology

C. Physical Technologies

(Construction, Manufacturing, and Transportation)

3.1. Unifying Themes

A. Systems

B. Models

C. Patterns

D. Scale

E. Change