

## London Bridge is Falling Down

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### INTRODUCTION

#### **Structural Engineering: Buildings and Bridges**

What prompted me to choose this theme from the many enticing topics offered at this year's Houston Teachers Institute introductory colloquium?

Perhaps it was recalling the awesome mixed feelings of apprehension and power when blasts of my air horn would alert the bridge tender that a thirty-two foot sailboat wished to pass beneath his iron girded section of the highway. Bells would ring, gates would drop, and both north and south bound vehicular traffic was brought to a halt while I circled cautiously beneath the slowly opening jaws of the bascule bridge that spanned the channel that led to the bay and, eventually, the Gulf of Mexico. With a wave to the keeper of the bridge, I would rev my engine and pass through, my mast now safely clear of the open overhead highway.

The narrow channel for two-way boat traffic was a tricky passage in that it was dominated both by the overhead bascule bridge and a few boat lengths away, a swing bridge for trains. Boaters knew that either bridge would close if an emergency vehicle needed to cross the bridge or a train was approaching; two important instances when a boat of any type or size does not have right-of-way. In the worst case scenario no sailor ever wanted to be caught in that no-man's-land between the two closed bridges, doomed to circle with other trapped souls in a tide impacted, narrow, and not too deep embayment.

The train bridge is gone; only the wooden and concrete piers remain. The bridge tender and the bascule bridge are gone, replaced by a higher bridge. I miss both.

With trepidation and respect I approach the remaining swing bridges and locks of the Inter-Coastal Waterway. And the thrill of a successful passage always outweighs the uncertainties.

Just as it did those many summers ago when we foolishly hiked above the arch bridge that spanned the fast moving Ottawa River and, swimming upstream, managed to negotiate between the second and third abutments, so as to float downstream, avoiding being sucked under the log jams, and swim safely back to the boom that kept the logs destined for the paper mill away from the shore. The thrill outweighing the uncertainties: the excitement of passing beneath the bridges perhaps more memorable than passing over them.

Thinking back to what I know about bridges, or more specifically to what I first remember about bridges and school, the song "London Bridge is Falling Down" comes to mind; a game-song played in a circle with other kindergarten students. Paradoxically, if we teach children that London Bridge is falling down (which it isn't), then why not teach them about what's keeping it, and others, up? My plan is to design this unit as a series of combined mathematics and science lessons embedded within the context of bridge design and construction as a way of connecting the subjects I teach (fifth grade math and science) to a historical overview of bridges.

## **PURPOSE AND THEME**

My goal is to create a type of student centered and student driven independent study project for my gifted students, rather than a step by step set of sequential lessons. Therefore this curriculum unit should be thought of as a guide for teaching a thematic unit based upon bridges for students of any age, rather than a specific ordered menu of lessons for the gifted only.

### **London Bridge Is Falling Down**

The Nursery Rhyme/Song

London Bridge has fallen down,  
Fallen down, fallen down,  
London Bridge has fallen down,  
My fair Lady.

Build it up with wood and clay,  
Wood and clay, wood and clay,  
Build it up with wood and clay,  
My fair Lady.

Wood and clay will wash away,  
Wash away, wash away,  
Wood and clay will wash away,  
My fair Lady.

Build it up with bricks and mortar,  
Bricks and mortar, bricks and mortar,  
Build it up with bricks and mortar,  
My fair Lady.

Bricks and mortar will not stay,  
Will not stay, will not stay,  
Bricks and mortar will not stay,  
My fair Lady.

Build it up with iron and steel,  
Iron and steel, iron and steel,  
Build it up with iron and steel,  
My fair Lady.

Iron and steel will bend and bow,  
Bend and bow, bend and bow,  
Iron and steel will bend and bow,  
My fair Lady.

Build it up with silver and gold,  
Silver and gold, silver and gold,  
Build it up with silver and gold,  
My fair Lady.

Silver and gold will be stolen away,  
Stolen away, stolen away,  
Silver and gold will be stolen away,  
My fair Lady.

Set a man to watch all night,  
Watch all night, watch all night,

Set a man to watch all night,  
My fair Lady.

Suppose the man should fall asleep,  
Fall asleep, fall asleep,  
Suppose the man should fall asleep?  
My fair Lady.

Give him a pipe to smoke all night,  
Smoke all night, smoke all night,  
Give him a pipe to smoke all night,  
My fair Lady. (Williams)

Is there a story here to be investigated? Indeed there is. Each stanza describes a different phase of the old Bridge's history that began during the Roman occupation of England. The bridge, which spanned the Thames River, was originally made of timber and clay and was fortified over the years with many of the materials mentioned in the song; "wood and clay, bricks and mortar, then iron and steel." It was attacked by Vikings in the 1000s and suffered many fires that necessitated using the different building materials.

The first stone bridge was begun in 1176 and took thirty-three years to construct. The twenty arches were thirty feet wide and sixty feet high, and the bridge included towers and gates. Peter de Colechurch, an English monk, engineer, and stonemason supervised the construction. The current of the river turned grist wheels beneath the bridge; while houses, apartments, shops, and a chapel were erected atop. By 1300 there were about 140 shops, some three stories tall, built upon London Bridge. The mention of silver and gold in the song refers to the shops that conducted business on the bridge.

The Great Fire of 1666 caused its arches and foundations to weaken, and resulted in thatched roofs being banned in London until 1994! The second London Bridge, begun in the 1820s, was built north of the old one. Eleven years later the 'new bridge' was opened, and the old one was razed.

The last three verses of the song refer to a "man." Was the "man set to watch all night," there to protect the bridge in case of fire, guard the shops, or keep strangers from crossing the bridge in the dark of night?

In the 1960s the bridge could not bear the demands of twentieth century traffic, so it was sold, shipped, and reconstructed stone by stone at Lake Havasu City, in Arizona.

Today the "third" or "newest" London Bridge stands strong in the southwestern United States (Alchin; "London Bridge, 1500").

The study of this bridge alone, which spans 800 years, has enough history, math facts, and science related events to keep a class busy for several weeks. I visualize using it as my "introductory bridge," the one I'll use to inspire my students. I will encourage them to search out facts about this bridge as a way of stimulating their curiosity about bridges in general.

### **Bridges as Inspiration**

In the beautifully illustrated book, *Bridges, Triumphs of Engineering*, the authors, Perino and Faraggiana, describe their selections as "examples that demonstrate the evolutionary process of bridges during different historical epochs around the world" (10). It is my intent that looking at bridges from a historical perspective will also enable my students to appreciate the impact that advancements in scientific knowledge have had on the construction of bridges over time.

This perspective also leads one to consider a social studies connection as well. According to Sorel's article, "The Integrated Curriculum," she feels "there is more overlap between social studies and science" than integrating science with mathematics (21). Even though I teach only mathematics and science, I intend to investigate this association.

The following National Curriculum Standards for Social Studies (NCSS 1994) include:

- Standard III: People, Places, and Environments
- Social studies programs should include experiences that provide for the study of people, places and environments.
- Standard VII: Production, Distribution and Consumption
- Social studies programs should include experiences that provide for the study of how people organize for the production, distribution, and consumption of goods and services. (Sorel 25)

It would be difficult indeed to explore the history of bridges and bridge construction without including some information about people, places and environments as well as discuss how bridges have impacted the production, distribution and consumption of goods and services.

Timelines are cross-curricular illustrations found in mathematics, science and social studies objectives. A dynamic "Bridge Timeline" could be created and used by the class to illustrate bridge construction and design. Have the students add and reposition bridges on the classroom chart as they collect more information throughout the year. Have the students list pertinent facts with the source on small index cards and turn them in for a grade or possible extra credit. Just as the construction of bridges has changed over time so will the classroom Timeline.

LaFontaine's *Bridges of the World Coloring Book* explores the history of bridge construction from Anglo-Saxon Stone-slab "clapper" bridges to the 1960's Verazano-Narrows Bridge, New York. He includes a Peruvian rope suspension bridge, as well as a Chinese "camel-back" arched bridge. There is just enough information included with each illustration to pique the curiosity of those researching science, mathematics and/or social studies facts. Additionally, in *Fantastic Feats and Failures*, the authors not only highlight engineering achievements as well catastrophes, but include what was learned from the mistakes and how the problems were rectified for the next project. This is an inspirational book in that it includes personal struggles as well as engineering obstacles that needed to be overcome.

## **THE STUDENTS**

My students are bright youngsters who both need and enjoy challenging projects. They are naturally inquisitive and delight in using the Internet to research facts and phenomena. Our district curriculum (Project CLEAR) complies with our state's mandated objectives set by the Texas Education Agency for core subjects, and includes formulated guidelines for addressing the needs of Vanguard (gifted and talented) students. Our Vanguard school for gifted youngsters K-8 is unique in that it also serves a deaf student population, a hard of hearing population, as well as the medically challenged. I believe the unit theme "Bridges" can be adapted to serve the needs of many different types of school populations and provide an excellent opportunity for curriculum integration.

Sometimes bright students work just "hard enough" and it is these "bright children who aren't motivated who are the most frustrating for parents and teachers" (Gibbs 47). Due to the fact that this is often the case in a Vanguard or Gifted (G/T) classroom, engaging and motivating themes such as "Bridges" are especially significant when they can be integrated into an existing curriculum.

Not only is it important for students to see how math and science are used in the world around us, it will also be enlightening for students to be introduced to the various careers and vocations that are involved in the construction of bridges. Bridges are structures so common in our large city (Houston, Texas) that we might otherwise not think about how or why they are created, and because of the current and seemingly endless construction of roadways and overpasses in Houston, it will be easy to observe first hand, the processes and workers involved. How many vocations *does* it take to build a bridge? Accordingly, I believe this topic affords my students a fascinating as well as practical knowledge of how mathematics, physics, and people are presently used to create structures important to our city as well as how they served civilizations throughout history.

This unit will require students to “think like an engineer” by using both a knowledge of physics and mathematics to solve typical problems faced by structural engineers. Because nomenclature is the language of a discipline, they will have to become familiar with the terminology pertinent to bridge construction. [Adapted from Scholars & Knowledge, Houston Independent School District’s framework for a differentiated curriculum, wherein thematic units, and “thinking like a \_\_\_” (physician, engineer, educator, etc.) will “emphasize a scholarly approach based on the state performance standards for gifted learners” (Boyd 14).]

### **THE THEME OF INQUIRY**

In as much as I would like this project to be “student driven” and inquiry or discovery based, I realize that students will need direction and guidance; however, I find it difficult to outline a step-by-step lesson process. What I am really counting on is for my students to determine the direction they will go. I envision developing this unit as a series of integrated mathematics and science activities related to bridge construction. This format will allow students to form concepts from hands-on problem solving experiences. For example, giving the students the problem of constructing a bridge over a given span, using three lengths of material each too short to do the job alone. Other simple inquiry and problem solving exercises that encourage experimentation and further questions involve using file cards to span a distance slightly narrower than the card, and test strength by adding uniform weights. Pennies, washers or mass weights can be used for “loads.” Experimenting with the file cards and paper, folded, pleated, or rolled etc. demonstrates how different design options affect the load a bridge is able to carry. The span can be the distance between stacked books or desks placed several inches apart. Walston’s *Building a Paper Bridge* or Science Explorer’s *File Card Bridges* each address these challenges. I believe this would be an effective way to engage the students and would serve as a springboard to the further study of bridges and bridge design.

Next we would examine the need for bridges; research basic types of bridges, such as beam, arch, suspension, cantilevered, or cable stayed. Hopefully the students would come across particular use bridges such as bascule, fixed, swing, lift, or pontoon. I would prefer having them discover different types in their own research, while having on hand back-up file cards of possible suggestions.

As a class we will explore the bridges they have discovered, how bridges have evolved over time through the use of improvements in materials, design philosophies as well as manufacturing and construction technologies. Referring back to the London Bridge verse, “wood and clay will wash away,” students could choose to investigate how river currents behave when constricted or their course is altered and determine how and why certain footings and foundations are designed and selected. These are questions that may lay more within an environmental approach to building bridges. For example, older students could determine the environmental impact bridges have on certain fragile environments, and discover if engineers and planners take these issues into account. Younger students might explore why wooden bridges are built across sand dunes.

Depending on their age and level of interest, students may choose to collect data on material costs and do cost analyses. They could calculate the present day costs of “replacing” existing bridges or might estimate the amount of traffic, time, and tolls needed to recover the cost of a local bridge, e.g., the Fred Hartman Bridge, which spans Upper Trinity Bay and the Houston Ship Channel. Perhaps by the end of the unit the students will be in a position to predict possible future bridge designs, as well as determine cost factors. The geometry of bridges and the costs involved may fall more within the grasp of older students, but should not be discounted if a student shows an interest in such topics.

As a class I would like to graph the spans of bridges across time, (a time line of spans?) and investigate the correlation between advances in physics and materials, to length of spans. I plan to create a file of “possible inquiries” to match students’ capabilities or interests. Usually there is a direct correlation between a student’s interest in a project and their final product.

The students will need to investigate the physical forces that keep bridges up and those that tear bridges down. Many relevant engineering and constructions terms and concepts will need to be introduced and explored. Terms and concepts involving tension, compression, torque, lateral force versus rotational force, load, stress, etc. will be included in a student “Pictionary,” a student’s personal illustrated dictionary of relevant terms. I envision testing different materials and designs in order for the students to better understand the terminology. Models using different materials: spaghetti, paper, toothpicks, popsicle-sticks, or commercial products such as Legos, K’NEX, etc., can be constructed to illustrate these forces, as well as to test design options. Plans are available at numerous web sites. Entering “bridge building” in a search request yields innumerable results. My students use glue guns for many of their projects, and I have recently experimented with a “cold” glue gun that remains cooler than the traditional gun, and the glue seems to harden quicker. Younger students would rely on white or wood glue, or parental helpers in the classroom.

## **THE UNIT**

This project will be based on a 3 to 6 week timeline, which will allow for enough time for the introduction, class related lessons, and collaboration with other teachers if needed, as well as give students time to research and complete their project. The time frame will need to be adjusted to the amount of work done at school versus the amount of work done at home. I will initiate a staggered due date to allow the students time to present their product. The student’s final product will include a ten-slide Power Point Presentation and a model. They will need to have a performance standards rubric for each section of their project that clearly defines the expectations and resultant scores. The students will need to maintain a work log with frequent checkpoints to assess progress and their “Pictionaries” and activity records will also be assessed.

In the event computers are not available to create Power Point Presentations, students could create a Bridge Timeline, based on specific requirements, (x number of bridges of a specific century, or type(s) over time). Perhaps themes such as Roman Bridges of Europe, Primitive Bridges of the World, or Bridges of Harris County (or your county) could be used.

In addition to our in-class cooperative Power Point Presentation and model building, I intend to use former fifth grade students’ products as examples of independent projects. One student’s History Fair topic was “the Brooklyn Bridge,” and another’s was a science fair project that examined how design affects the strength of a bridge.

Our P.T.O has purchased 8 K’NEX education *Bridges* kits, which I will use towards the end of this project, as I want the students to first experience basic model building using and testing materials found in the home, or inexpensively purchased, and be somewhat familiar with the terminology and designs before constructing the kit models.

## Independent Studies

As a class we will research the London Bridge, its history, math statistics, and engineering facts. We will brainstorm on how math and science relate to its construction and longevity. We will build a model of this bridge, and create a Power Point Presentation. This should set the parameters and expectations for the student independent projects.

The students' Independent Projects will include mathematics and science components as well as incorporate technology by requiring a Power Point Presentation and a Model of a Bridge based on their research. As yet I have not examined our fifth grade Social Studies objectives, nor formulated on how best to incorporate this "potential for *content* (sic) to cross over" (Sorel 21), as I have not discussed this option with my teaching partners. However, I do intend to include a classroom timeline that should include the periods of United States history that is taught in our fifth grade classes.

I attended an "Independent Study" workshop at the November 2004 TAGT (Texas Association for Gifted and Talented) Conference in Dallas, Texas. Each participant was given a copy of an overview of a course, available as an elective for seventh or eighth grade students in the Katy Independent School District. According to the presenters, Cathy Wappler and Sherry Luce, the purpose of an independent study is to allow "gifted and talented students to explore a field of interest to them and to design and complete products which demonstrate their learning in that area" (unpaged handout, but also included in our GT curriculum).

One key element of an independent study elective is that it requires that the students access experts outside the classroom. I feel that in using the Internet to research their bridges, the students are stepping outside the classroom to gain knowledge. Perhaps we could include parents with engineering or related backgrounds to consult with us about our projects; also, we could invite engineering students at the University of Houston to comment on our work or model building.

With this concept in mind I hope to be able to prepare my students for future independent study projects by having them access "outside experts" and completing their projects outside the classroom. Usually, when independent studies are presented as an elective, the students complete their work in school, using an "outside" expert of their own choosing as an advisor.

The students will be presented with a list of themes from which to choose, or determine their own. Theme suggestions, with examples could be available on index cards. This would give both the teacher and students a resource bank that could be supplemented and updated over time.

## Organizing the Unit

I have decided to create this unit using five by eight inch index cards. A different color will be used for each of the following headings: Activities, Specific Bridges, Bridge Types, Themes, Terminology, and Time Line. This will enable me to easily add or delete ideas, as I want to be able to maintain the dynamic structure of the unit. For example, The Activities cards would include hands-on discovery lessons, such as Paper Bridges, File Card Bridges, News Paper Bridge Contest, Building Models, etc., as well as the instructions for creating the "Pictionary."

The Specific Bridge Cards would give the name of a Specific Bridge, place, dates, persons involved, and bridge facts (type, height, spans, etc.) and any unique information. For example the information for one of the London Bridge cards might read "New London Bridge;" London England, crosses the Thames River; 1824-1831; John Rennie designer, died before bridge was begun, son, Sir John Rennie took over; 5 elliptical arches, total span 1005 feet, central span 150 feet wide, roadway 56 feet widened to 75 feet. It replaced the 622-year-old "Old London Bridge"

(LaFontaine 23). Golden Gate Bridge, San Francisco Bay, 1933-37, Joseph Straus architect, dies year after completion. (Nelson 31).

The Bridge Types cards, would include the descriptions and examples of the basic Beam, Arch, Suspension and Cantilever bridges with additions such as Cable-stayed, Bascule, etc. added as they came up in the readings or research. (K'Nex Teacher Guide 3)

The Terminology cards would include terms, and pictorial examples for words such as cantilever, truss, load, force, compression, torque, stress, tension, lateral force vs. rotational force, stress, etc. Items can be added, altered or deleted as the research progresses. My students will be creating a "Pictionary" or visual dictionary of technical terms based on the terms we choose from this file.

The Time Line cards will group bridges into centuries according to the dates they were built. This will help me with the Classroom Time Line.

The Theme cards will include suggestions that are open-ended special interest options or themes the students might choose for their particular project. Such options might include: the aesthetic versus the practical; famous and not so famous bridges; the ones that stayed up as well as the ones that came down, or even customs relating to bridges. (As an example, the class rings of the graduating Engineering students at Queens College, Kingston, Ontario, Canada, are historically made from material of a failed bridge).

Students might choose to focus on the origins of the nursery song "London Bridge is Falling Down" or perhaps investigate bridges that are mentioned in other songs, rhymes, or literature.

Bridges of famous designers or bridges with a unique history or story to tell could be researched. I think it would be fun to include "One Phenomenal Fact," and a "Brief Biography" of the engineer or designer if known, for each of their bridges. Do not the names Kingdom Isambard Brunel, or Eiffel, invite investigation? How about those sons who completed their fathers' projects? One example being, Washington, son of the Brooklyn Bridge's designer, John Roebling, another the John Rennies associated with the "second" London Bridge.

Additionally, environmental issues that affect the integrity of bridges (salt water, air pollution, wind, and water currents, and weather) could be explored.

These themes will be collected to use as a way of generating research topics for the students' independent projects. Although I see the card system as practical way for me to organize a dynamic unit, this card system should allow for easy updates and access by students as well.

### **Using the Internet**

At our school we have signed permission slips from parents allowing their children to use the Internet at school, and we also have access to the computer lab for students who might not have Power Point on their home computers. Our computer instructor teaches our fifth graders how to create ten or twelve slide Power Point presentations each year. Our Science Lab instructor would also be available to help with the physics lessons if needed. The Art teacher has allowed my students to use her room for messy projects. Similar help would also provide additional opportunities for integrating curriculum.

With Internet safety an issue, it would be prudent to have an agreement outlining the project and Internet requirements to be signed by both parents and students before beginning. I would like to include a copy of Anita Perry's (our governor's wife) letter to Superintendents regarding the Internet Keep Safe Coalition, which addresses Internet safety. Their web site: [www.iKeepSafe.org](http://www.iKeepSafe.org). The letter is available on the Texas Education Agency's web site.

Requiring parental signatures for this project should bring up issues that could be resolved before deadlines need to be met. For example, those students who do not have access to the Internet or the needed software at home could arrange to complete segments of the work at school.

## TEACHING THE UNIT

**Introductory Activities** (see Lessons)

### KWL Chart

Generate a KWL Chart; (Three columns on a sheet of bulletin board paper. It is used to keep a running summary of what students **K**now, **W**ant to know, and have **L**earned, as activities progress.

### ALL ABOUT BRIDGES

<b>I Know</b>	<b>I Want to Learn</b>	<b>I Learned</b>
Bridges cross water	How do they build a bridge across deep water?	Some bridges are called suspension bridges
Bridges cross highways	What is a suspension bridge	Tall towers and cables hold up the roadway
Some are very long	Can they build a bridge across an ocean?	There is a bridge between Prince Edward Island and New Brunswick, Canada
Some are very high	What is the highest bridge in the world?	
I've been on the Golden Gate Bridge	Where is the Golden Gate Bridge?	It crosses San Francisco Bay Suspension, > 1 mile long
Some Bridges open		
Some Bridges are built for trains		

*Fig 1. An example of a KWL chart, with possible responses from the students.*

### Pictionary

Have the students define the word “bridge” without using a dictionary or other source. Then have them research the word on the net, or use a dictionary to see how many definitions are there for this word alone, (I found thirteen). Explain how you are using a specific definition and that their research will be within this context. Students begin their “Pictionary” with the word bridge, its definitions and pictorial examples of bridges. Students are to include the definitions and/or illustrations with the terms that are introduced in the activities. The students can complete this exercise for homework and share their findings the next day. Early examples will probably include the basic types of bridges, such as arch, beam, suspension, etc. and then the students can find examples of each type. (Figure 2)

### Pictorial Overview

At this time I would like to present a visual overview of Bridges -- photos borrowed from my professor, pictures I have taken and collected as well as books mentioned in the bibliography.

Can they identify some of the bridge designs? Do they recognize or have they traveled across any of the bridges? (Prepare to present this again before they begin their independent project.)

### **London Bridge Research** (as a class)

What do students discover about London Bridge following the investigative format of asking who, what, where, when, why, and how? Bring data to class and select items for Power Point.

### **The Power Point London Bridge**

Students can work in pairs or groups to create slides for the classroom project. Slides should include illustrations, sketches or photos over time and a history of the three main phases of its existence. When was it built? Include dates and bridge data. Where is it located? Why it was built, rebuilt and eventually sold and moved to another country? How was it built? How was it moved? Include interesting facts. What made it “special”? Why does this particular bridge have a nursery rhyme and song about its history?

### **The London Bridge Time Line**

Build a time line for London Bridge based on data gathered by the students. This could be part of the Power Point Presentation. Nelson in *The Golden Gate Bridge* includes a Timeline (31).

### **The Model, London Bridge**

Students can follow model building activities, and then:

Determine the stage, or section and what materials to use, perhaps a K’NEX arch with toothpick houses atop. It will depend on the timeframe and suitable materials. Etched and carved Styrofoam might be a possibility.

This project will then be available as a model for future classes, and although the whole process will not have to be repeated, additions or deletions can be made based on future class work. (For example, which bridge did the folks in Arizona think they were really buying?)

### **Independent Project**

Discuss the Independent Project. Have students choose a bridge or theme and allow time for them to review and change their initial choices. Determine if this is to be an individual or pair project. Each student must be responsible for his/her section. Discuss how the work is to be divided fairly.

Students must have a performance standards rubric for each section of their project. Such standards would clearly define the expectations and resultant scores (Lantz 90). The students will need to maintain a work log with frequent check points to assess progress. The Independent Project includes a ten-slide Power Point Presentation, and a model.

## **HANDS-ON LESSONS**

Having the students form a hypothesis, test it, record the outcome, and discuss the results is an important part of these introductory lessons. Discuss Variables. Which would be the dependent and the independent Variable s? Possibly graph the results.

### **Lesson One: Paper Bridges**

Introductory Activity: (See bibliography and check Internet for additional sources.) Students will be investigating beam bridges and load factors.

## ***Materials***

### For each student

Recording Worksheet or Science logs to record Predictions, methods, materials, and results.

For each group or pair of students:

4 to 6 textbooks (enough to make 2 stacks the same height)

2 or 3 sheets notebook or computer paper

Bowl of 75 pennies or washers. (I will use gram mass weights)

## ***Procedure***

1. Make 2 even stacks of books with a gap of about 4 inches between them.
2. Make a bridge using the paper as the bridge and the books as the piers, or supports.
3. Predict and record the loads; how many pennies or how much weight (mass) can be placed on this “flat bridge” before it falls into the gap? Try it. Record your results. Discuss the results. Try adjusting the distance between the books (the span). Is there a correlation between the span and the load?
4. The teacher then guides the students with the following instructions or questions:  
“Next, without adding anything to the paper, try to make your bridge stronger or stiffer.”  
Have the students experiment with different ways of using the paper (folded, pleated, etc.)  
Does folding on the long axis or short axis make a difference? Discuss and record results.

## **Lesson Two: File Card Bridges**

This problem-solving, hands-on discovery lesson has the students building beam and arch bridges without realizing it, and the large amount of pennies needed to cause the bridge to fail (collapse) really makes a point about the strength of the different types of bridges. I have adapted the following lesson “File Card Bridges” from the 3 page lesson available through the Internet. I would change it in order not to “give away” surprise results. The pleated bridge will support almost 400 pennies (rolled) or about 2 ½ pounds, so start saving pennies if you wish to use this lesson. A roll of pennies weighs about 132 grams (*File Card Bridges*).

## ***Materials***

### For each student

Recording Worksheet or Science logs to record predictions, methods, materials, and results.

### For the class

Several packages of three by five inch index cards and at least 300-400 pennies (six to eight rolls) or washers (Have about 8 extra rolls available).

## ***Procedure***

1. Make 2 even stacks of books with a gap of about 4 inches between them.
2. Make a bridge using the index card as the bridge and the books as the piers, or supports.
3. “About ½ inch of the card should be resting on a book at each end.”  
(*File Card Bridges* 1)

The teacher then guides the students with the following instructions or questions:

- What happens if you fold the card in half?

- Can you pleat the card?
- Form an Arch?

An arch can be constructed using identical books for piers or abutments, and topped with a second card.

(I will use a triple beam balance scale and metric units in my class to measure loads)

4. Predict and record the loads; how many pennies or how much weight (mass) can be placed on the “flat bridge” before it falls into the gap? Try it. Record your results. Compare the beam and arch “bridges.” Discuss the results. Ask the students if there were any surprises.

### Lesson Three: Pictionaries - Bridge Types

If researching “bridge types” is a homework assignment, then have the students bring to class their findings in order to begin their illustrated dictionary of terms or “Pictionary.” A list of terms follows the lessons.

#### Materials

For each student

Bradded folder, with pockets, and lined paper for “Pictionaries”

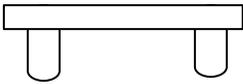
For the class

Have on hand examples of beam, truss, arch and suspension bridges. Examples are Bridge Type and Terminology File Cards (Figure 2), prepared Power Point Overview, videos, photos on a CD, books and pictures brought in by students.

Give a brief overview of bridge types and have the students find examples of beam, truss, arch and suspension bridges using the Internet, books you have brought into the class or file cards.

Have the students write a definition for each bridge type in their Pictionaries, and include an illustration which will help them compare and understand the different types of bridge designs. I personally feel it is best if they draw their own illustrations, rather than cut and paste ones from Internet sources. Add terms as you come across them in your research and activities (Figure 2).

#### Terminology Cards

<b>Arch Bridge</b> 	<b>Beam Bridge</b> 	<b>Cantilever Bridge</b>	<b>Suspension Bridge</b>
<b>Load</b>	<b>Dead Load</b>	<b>Live Load</b>	<b>Compression</b>
<b>Tension</b>	<b>Torque</b>	<b>Stress</b>	<b>Force</b>

<b>Arch Bridge</b> 	<b>Beam Bridge</b> 	<b>Cantilever Bridge</b>	<b>Suspension Bridge</b>
<b>Abutment</b>	<b>Beam</b>	<b>Cable</b>	<b>Caisson</b>
<b>Decking</b>	<b>Pier</b>	<b>Span</b>	<b>Truss</b>
<b>Engineer</b> Lucious Fabricius ~ 62 B.C. (LaFontaine 7)	<b>Architect</b>	<b>Designer</b> Thomas Telford ~ 1820 (Feddon 439-441)	<b>Gephyrophobia*</b>

Figure 2. Some terms and possible entries for the Terminology Cards to be used with the students' "pictionaries" adapted from (K'Nex, 3-4)

\* Challenge term: What is the word for fear of crossing bridges? Another challenge is to have the students research the definitions for Engineer, Architect and Designer, and discover if these meanings have changed over time.

#### Lesson Four: The Bridge Design Challenge

After a brief review in which we share the examples brought in by the students, I would challenge them to design a simple bridge from the materials provided within a specified time.

The Challenge: Their bridge will need to span a distance of one meter.

For each pair of students allow 15-20 minutes. (Individuals, allow 10 minutes)

#### Materials

For each pair of students

Prepare a large Zip lock bag

Include 5 sheets of newspaper, 25 paper clips, a 30-cm strip of masking tape, a meter measuring tape, and uniform items to act as a load. (mass weights, washers, rolls of pennies)

Two chairs and a *Record Sheet*, top half for design, and bottom half for recording loads.

I usually precut masking tape and lightly stick it to their desks or to their "supply bags."

The students will use their own chairs and class meter sticks if there aren't measuring tapes available.

#### Procedure

1. Use only the given materials to design and build a bridge to span 1 meter.

2. Use the weights to measure the load it carried *before* collapsing.
3. Record your results, and include a sketch of your design.

At the end of the given time, each pair of students will describe their bridge and the load it carried before collapsing. The teacher could add “wind” if there is a fan handy. A Classroom Graph could display Design Types and Loads for each pair of students. (adapted from Garrison 31)

<b><u>Bridge Design Challenge Record Sheet</u></b>	
<b>Our Bridge Design</b>	
Type: _____ Designed by: _____ & _____	
<b>Recorded Loads</b>	
Mass (Live Load)	Observations
	<b>Failed, collapsed</b>

*Figure 3, A sample Record Sheet for Activity 4*

### **Lesson Five: Cantilever Bridges. Balance and Counterbalance**

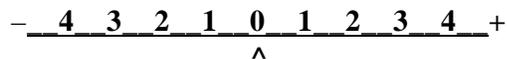
***Materials:***

For a class of 24 students make the following.

For the levers: 10 ft. x 1 3/8 in. wide lathe strip, cut into six 20-inch lengths

For the fulcrums: half-round molding cut into 1 3/8 in lengths. Make extras. (Materials can be found at Home Depot, Lowe’s, or any lumber yard; I used a coping saw.)

Divide each lever into ten, 2-inch increments. Number from center 0, to either end.



Use the 1 3/8 inch long, half-round as the fulcrum, (flat side down, rounded side up).

### For each group of four students

1 lever, 1 fulcrum, about 12 pennies (washers or mass weights) and record sheets or logs

Take turns and record the results.

1. Balance the lever on the fulcrum.
2. Experiment balancing the lever with equal amounts of pennies on lines equidistant from the center, e.g. three pennies at both +3 and -3.
3. Next move the fulcrum and change the loads to discover the relationship between lengthening the arm on one side and increasing the load on the shorter arm.

Record your observations.

This is a good introduction into understanding cantilevered bridges. Balance and counterbalance are also important features of Bascule bridges.

Rulers, yardsticks, or 5 gallon paint sticks could be substituted for the levers, but the half-round molding makes good fulcrums by providing a most precise point of contact. For a larger class I would have each group rotate and compare the different items, while always using the half-rounds as the fulcrums.

### **Other Model Building Lessons**

The book *Bridges*, contains instructions for building a Truss Bridge using Popsicle sticks (Johnmann, 41).

Enlarge a truss pattern to fit the size of the materials being used, (Popsicle sticks or toothpicks), and place it underneath a sheet of wax paper so that the students have a pattern to lay their pieces upon before gluing. The wax paper would make it easy to remove the finished truss, and the protected pattern could be used over.

The book *Fantastic Feats and Failures* contains several construction models using items such as spaghetti, toothpicks, marshmallows, and gumdrops. Think of ways to use these materials.

Some web sites provide paper models of bridges that can be printed, enlarged and constructed. Perhaps you would allow this type of model to accompany the Power Point Presentation.

### **Summary**

I believe any hands-on problem solving activities will enthusiastically engage students, and serve as an excellent component of the unit. I intend to collect many different activities to add to my Activities Card File, and look forward to initiating this unit and seeing how it develops over time.

### **ANNOTATED BIBLIOGRAPHY**

#### **Works Cited**

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Boyd, Cyndi, et al. *Scholars and Knowledge: A Scholarly Approach to Learning*. Curriculum Guide. Houston: Houston ISD, 2003.

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<[http://www.exploratorium.edu/science\\_explorer/card\\_bridge.html](http://www.exploratorium.edu/science_explorer/card_bridge.html)>.  
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This very informative and fun to read book, by the editors of *YES Mag*, science magazine helps youngsters understand science, engineering and technology concepts. It matches photos and diagrams with 20 famous engineering feats, some successful, some not. The book includes what the failures taught the engineers and how the problems were resolved for future work. Several problem-solving activities are included to help youngsters grasp concepts. 52 pages available in soft or hard cover editions.
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A very informative book that describes different types of bridges, their history, safety, and dilemmas, includes terminology, designing, building and testing activities.
- K'NEX, *Introduction to Structures: Bridges. Teacher's Guide*. Hatfield, PA: K'NEX Industries, 2003.  
This is the very informative teacher's guide that comes with the K'NEX Bridges Kit. The kits contain the necessary pieces for constructing 7 different types of bridges. The lessons are hands on, inquiry based and include problem solving activities, worksheets and ideas for journal entries. One kit and the guide would be very helpful to model different bridge types. If the teacher's guide can be purchased separately, it would prove very useful.
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The March issue of *Science & Children* featured articles supporting integrating science with social studies. I found Ms. Sorel's article most enlightening, and am now discussing this possibility with my teaching partners as I only teach science and math.
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- Williams, Sue. *All About Nursery Rhymes: London Bridge*. 2003. All Info About. 27 Mar 05. <[http://nurseryrhymes.allinfoabout.com/london\\_bridge.html](http://nurseryrhymes.allinfoabout.com/london_bridge.html)>.  
This website is all about nursery rhymes, their history and origins. Ms. Williams also has an all about poetry website as well.

## Supplemental Resources

Corbeil, Jean Claude and Ariane Archambault, eds. *The Macmillan Visual Dictionary*. New York: Macmillan, 1992.

This book graphically illustrates types of both fixed and movable bridges. Pp. 454-457.

Macaulay, David. *Castle*. Boston: Houghton Mifflin, 1977.

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These two books are detailed sketches of how Castles and Cathedrals are constructed. They would make a useful reference for students to compare architectural features of bridges and buildings.

Mark, Drew. "The Brooklyn Bridge." A fifth grade history project.

This project was researched and produced by a fifth grade student at Lovett Elementary school. A model project to show an example of an interest driven independent study project.

Taylor, Beverly, A. P., J. Poth, and Dwight J. Portman. *Teaching Physics with TOYS: Activities for Grades K-9*. Middletown, OH: Terrific Science Press, 1995.

A 296-page book published through Miami University Press. Many teachers and professors collaborated to make this an excellent resource of lessons that teach the laws of physics through the use of toys and games.

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"London Bridge is Falling Down" (also known as "My Fair Lady" or "London Bridge") is a traditional English nursery rhyme and singing game, which is found in different versions all over the world. It deals with the depredations of London Bridge and attempts, realistic or fanciful, to repair it. It may date back to bridge-related rhymes and games of the Late Middle Ages, but the earliest records of the rhyme in English are from the 17th century. The lyrics were first printed in close to their modern form. The theory that London Bridge is Falling Down refers to this practice was first recorded by Alice Bertha Gomme in "The Traditional Games of England, Scotland and Ireland" (1894-1898). The idea is that London Bridge would fall down unless human sacrifices were buried in the foundations. There is, however, no archaeological evidence of any human remains in the foundations of London Bridge. So immurement is not likely to be the inspiration behind this nursery rhyme.

Build it up with silver and gold  
Silver and gold, silver and gold  
Build it up with silver and gold  
My fair lady.

London Bridge is falling down  
Falling down, falling down  
London Bridge is falling down  
My fair lady.

About. Mother Goose Club  
Sings Nursery Rhymes, Vol. 7: Kids Sing & Learn. Mother Goose Club.

Down by the Bay. Driving in My Car With Eep the Mouse.  
Winter, Spring, Summer and Fall. Skidamarink. Six in the Bed. London Bridge Is Falling Down. An animated version of the popular children's nursery rhyme 'London Bridge is falling down' with lyrics.

London Bridge is falling down.  
London Bridge is falling down,  
Falling down, falling down,  
London Bridge is falling down,  
My fair lady.

Build it up with wood and clay,  
Wood and clay, wood and clay,  
Build it up with wood and clay,  
My fair lady.

Wood and clay will wash away,  
Wash away, wash away,  
Wood and clay will wash away,  
My fair lady.

London Bridge is falling down,  
Falling down, falling down,  
London Bridge is falling down,  
My fair lady.

Build it up with silver and gold,  
Silver and gold, silver and gold,  
Build it up with silver and gold,  
My fair lady.

Gold and silver I have none,  
I have none,  
London Bridge was indeed "falling down" several times over the years, being re-built stronger again and again. The song has become one of the most popular singing-games among kids over the world, being translated and adapted in many languages, especially in European countries such as Denmark: "Knippelsbro Gar Op og Ned", France: "Pont chus", Italy "Le porte", Germany: "Die Magdeburger Bruck" and Romania "Podul de piatra".

Two kids are making an arch holding their hands up, face to face and the rest of them, are passing under the arch, one by one, creating a circle. They continue to walk under the arch, one by one in circle. When the last word of the verse is said (the "My fair Lady") the two children who form the arch have to capture one child by dropping their hands down.

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London Bridge Is Fallin' Down " Count Basie. 2:58. London Bridge Is Falling Down " The Diller-Quaile School of Music. 2:25. London Bridge Is Falling Down Original " The Tiny Boppers. 1:48. London Bridge Is Falling Down - Musica para bebes - Canciones de cuna " Canciones para Ninos, Musica para Bebes Especialistas, MÚSICA PARA NIÑOS. 1:54. London Bridge Is Falling Down " Mediaeval Baebes. 2:34. Carousel " Dominic Alldis. 3:22. London Bridge Is Falling Down " Justin Ryan. 2:25. London Bridge Is Falling Down " Jimmy Rushing. 2:54. London Bridge Is Falling Down " Mr. Tommy. 5:02. London Bridge Is Falling Down " Billion Smiles Project. 4:31. London Bridge is Falling Down " Little Boy Blue. 3:07. London Bridge Is Falling Down " Å`yen. 1:54.