AOE POE Integrated Curriculum Unit: Bridge Builder

Lesson 3.1

U.S. History

Building the Brooklyn Bridge

In this lesson, students examine the construction of the Brooklyn Bridge within the historical, social, and political context of the late 1800s.

This lesson is expected to take two class periods.

Lesson Framework

Learning Objectives

Each student will:

- Describe how the Brooklyn Bridge is a structure representative of the technological innovation and progress of the late 19th century.
- Explore the complex relationship between entrepreneurs and immigrant labor during the late 19th century, including the examination of a labor dispute and its resolution from multiple perspectives.

Academic Standards

- Understands how the rise of corporations, heavy industry, and mechanized farming transformed American Society. (NCHS National Standards for U.S. History—Era 6, Standard 1)
- Understands massive immigration after 1870 and how new social patterns, conflicts, and ideas of national unity developed amid growing cultural diversity. (NCHS National Standards for U.S. History—Era 6, Standard 2)
- Understands the rise of the American labor movement and how political issues reflected social and economic changes. (NCHS National Standards for U.S. History—Era 6, Standard 3)

Assessment

Assessment Product	Assessment Criteria
19th-Century Invention commercial	Teacher Resource 3.1.1—Activity: 19th-Century Commercials
Caisson Workers Strike roleplay	Assess based on involvement, whether student stayed in character, and appropriate write-up

Prerequisites

- Introduction to the Gilded Age
- Working knowledge of concept of Social Darwinism
- Standard U.S. History instruction up to the 1880s

Instructional Materials

Teacher Resources

- Teacher Resource 3.1.1—Activity: 19th-Century Commercials
- Teacher Resource 3.1.2—Background Information: Brooklyn Bridge Construction

Student Resources

- Student Resource 3.1.1—Reading: Innovations
- Student Resource 3.1.2—Roleplay: Caisson Worker
- Student Resource 3.1.3—Roleplay: Bridge Company Official
- Student Resource 3.1.4—Roleplay: Unemployed Immigrant
- Student Resource 3.1.5—Roleplay: General Public

Equipment and Supplies

- *The Great Bridge*, by David McCullough

Lesson Steps

Step	Min.	Activity
		CLASS PERIOD 1
1	**30**	**Commercials: 19th-Century Inventions** Cut up the list of 19th-century inventions in the Teacher Resource 3.1.1. Form students into pairs and have them select an invention from the 1800s at random. Give students about 10 minutes to come up with a 15-second commercial for their invention aimed at a 19th-century audience that has never seen the invention before. Students should use what they know about the actual invention to come up with a catchy slogan and some descriptions of how the invention will "change your life for the better." These are mostly common items that students should be familiar with, but you can provide a little background information from the links embedded in the list, if you prefer. Have each pair perform their commercial. Students may be surprised at what had and hadn't been invented in the 1800s.
2	**20**	**Reading: Brooklyn Bridge Innovations** Tell students that the Brooklyn Bridge, which was under construction from 1869 to 1883, symbolized innovation and progress during the late 19th century. The building of the bridge entailed two great technical challenges. The first was the building of the massive stone towers that bear the entire weight of the bridge and allow for the necessary clearance beneath. The second was the construction of the four enormous cables with the strength to support the central span and anchorages strong enough to hold them in place. These two elements of the bridge, one working in tension and the other in compression, needed to be in balance for the bridge to stand. The Brooklyn Bridge was the first to use steel for its cable wire and the first to use pneumatic caissons (the watertight structure used when digging the foundations). Pass out the Student Resource 3.1.1, the Innovations reading, and have students read individually or as a class. Answer the following questions as a class: • What were the two major innovations developed for the Brooklyn Bridge? • What was the benefit of inventing the steel rope for Roebling's design? • What was the benefit of the caisson innovations? If at all possible, go to the public library to obtain some illustrations of the caissons for use in class, because it may be hard to describe them for students. Your best source is probably contemporary sketches that appeared in *Harper's Weekly, Scientific American,* and other periodicals, which show both cutaway drawings and illustrations of the type of work carried out by the men inside. One particularly dramatic photograph shows the immense size of the Brooklyn caisson prior to launching, with the scale provided by the comparatively small men standing on top. Some of these drawings can be found online at: **http://www.brooklynmuseum.org/research/digital-collections/brooklynbridge/harpers/**

Step	Min.	Activity
		http://www.endex.com/gf/buildings/bbridge/bbridgenews/AmHist/AmHist0473.htm Washington Roebling described the caisson as a huge diving bell built of wood and iron, shaped like a gigantic box with a heavy roof, strong sides, and no bottom. Filled with compressed air, it would be sent to the bottom of the river by building up layers of stone on its roof. The compressed air would keep out the water and make it possible for men to go down inside and dig out the riverbed while the tower continued to be built on top. Eventually the caisson would reach bedrock at which point it would be filled with concrete and become the foundation of the tower. For homework, you can have students conduct a little of their own research on caissons and list all the technological advances that were necessary for the caissons to work. This should include steam power, air compressors, air pressure gauges, air locks, and inventions specific to this task such as the ingenious method of removing the dredged material from the caisson without losing pressure or using time-consuming air locks. You may also wish to assign the reading from Student Resources 3.1.2–3.1.5, the Caisson Workers Strike Roleplay materials, to save time in the next class period.
		CLASS PERIOD 2
3	**10**	**Mini-Lecture: Hazardous Work** Tell students that despite the safety innovations put in place, working on the bridge was still very dangerous. Some of the worst accidents of the bridge construction happened during the cable rigging. In June of 1878, a cable strand secured at the New York anchorage broke loose during adjustment. The strand flew over the New York tower and into the East River, taking off the top of one rigger's head and knocking another off the anchorage along the way. Another rigger was guiding wire onto a drum. He kicked at it to keep it in line, and his foot was caught. His leg was wrapped around the drum, killing him almost instantly. Several others died due to falls or falling equipment. A couple of men were crushed by blocks being swung into place. Overall, about 27 people died during the construction of the Brooklyn Bridge. Working below was no less hazardous. The nemesis of all workers in the compressed-air caisson was **the bends.** The bends is an extremely painful, and sometimes fatal, condition caused when a person is exposed to a rapid decrease in pressure. At high pressure, more inert gases from the air (such as nitrogen) are dissolved in the blood stream. When pressure is suddenly reduced, the gases are quickly released, just like when you open a soda bottle and it foams up. When a person moves from a high-pressure location straight to a lower pressure area, the nitrogen that was dissolved in the blood bubbles out. This bubbling causes the symptoms known as the bends. Since caissons are underwater, the compressed air constantly being pumped in kept them at very high pressure. Leaving the caisson to return to the surface outside was a rapid decompression. At least three men died of the bends (then called caisson disease) during the caisson work. At the time of the Brooklyn Bridge construction, little was known about the causes of these painful attacks—and little could be done to prevent them. Nearly all caisson laborers were inflicted by the bends to a certain extent.

Step	Min.	Activity
		In the case of the Brooklyn Bridge, 15 percent of those who got the bends were paralyzed to some degree. Some success with fighting the bends was achieved by a Dr. Janimet, on the St. Louis Bridge. He was the first American to hit upon the idea of slow decompression (the British and French had known it for years). Unfortunately, James Eads, the builder of the St. Louis Bridge, had a falling out with Washington Roebling and never shared his discovery. Fear of the bends was what caused Roebling to halt the excavation of the New York caisson; he estimated that upwards of 80 men would die if he tried to excavate any further. Washington Roebling himself did not escape the construction of the caissons unharmed. He liked to be on site during the construction, and could often be found inside the caisson instructing others what to do and even doing manual work himself. Washington Roebling actually spent more hours in the working chamber than anyone else; for fear that any mistake might be disastrous. One afternoon in the summer of 1872, Washington Roebling had to be carried out of the caisson with caisson disease. From this point on, he remained painfully paralyzed and was never able to return to the site of the Brooklyn Bridge. Roebling was determined to see the construction of the bridge to completion. He watched the bridge from his townhouse using a telescope, and directed the construction using his wife, Emily, to relay his instructions.
4	**40**	**Roleplay: Caisson Workers Strike** Divide the class into four equal groups: bridge company directors, caisson workers, unemployed immigrant workers, and the public. Have students read pages 195–199 and 303–305 from David McCullough's *The Great Bridge* for background information. Students should be familiar with the book, since they previously read excerpts in Lesson 1.2. You may choose to spend longer on this activity and give students the chance to conduct some research on their own. For the roleplay, each student can create a unique persona for themselves, but in general • The caisson workers will report on conditions in the caissons and the effects of "caisson's disease" and will vote to strike for higher pay, demanding $3 for a four-hour day. • The company directors should explain the budgetary pressures they face and refuse to offer more than $2.75 for an eight-hour day—which was in fact a very generous offer for that era. • The unemployed immigrant workers should express a desperate willingness to take a job for such great pay if the caisson workers don't want it, but must consider whether they would be willing to cross the picket line. • The general public can be creative and express any opinion as long as it is consistent with their chosen background and the general attitudes of the day. Their opinions may well have the effect of bolstering or weakening the strike. The public should be aware that because the bridge is being funded with public money, as citizens of New York they have every right to make their opinion known. The critical decision point in the roleplay is when the company directors threaten to fire all the strikers if they don't return to work immediately for $2.25 a day. At that point the strikers must decide whether they have the resources to resist further and whether it is

Step	Min.	Activity
		a greater risk to return to work or to give up the job. The company directors are certainly welcome to begin making offers to the unemployed immigrants while the strikers consider their situation. In reality, after three days of negotiations, the director of the bridge company simply announced that any man who did not go back to work immediately would be fired. With that, the strike ended, as the men decided that it was better to take the risks at $2.25 a day rather than have no job at all. For homework, have each student write a short paragraph describing their position on the strike and explain any changes in position that took place during the lesson.

Extensions

Explain to the class that business leaders at the turn of the century were alternately referred to as “robber barons” because of their ruthless tactics, and “captains of industry,” due to their entrepreneurial spirit.

One key business leader of this time was John Roebling, the founder of John A. Roebling’s Sons Company. Roebling’s company originally began as wire rope producer, but eventually expanded into the bridge building business. Have students explore the history of Roebling’s company at their online history site: **http://www.inventionfactory.com/history/main.html**.

While students read, tell them to make note of Roebling’s response to innovations, increased demand for wire rope, tariffs, and opportunities presented in the wire cloth business. Have them conclude whether Charles Roebling was a “robber baron” or a “captain of industry.”

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Student Resources

Resource	Description
Student Resource 3.1.1	Reading: Innovations
Student Resource 3.1.2	Roleplay: Caisson Worker
Student Resource 3.1.3	Roleplay: Bridge Company Official
Student Resource 3.1.4	Roleplay: Unemployed Immigrant
Student Resource 3.1.5	Roleplay: General Public

Student Resource 3.1.1

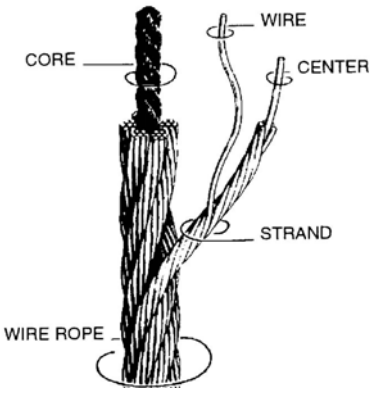
Reading: Innovations

Adapted from http://www.endex.com/gf/buildings/bbridge/bbridgefacts.htm

Wire Rope Cables

Building the Brooklyn Bridge not only required designing the bridge but also inventing key materials, their means of manufacture, and the means to put them in place. In the 1840s John Roebling started America's first wire rope manufacturing company. This got him involved in engineering projects that involved the use of his wire rope, and eventually in the design of suspension bridges.

Wire rope is made from strands of metal precisely organized to move together under load so as to maximize the working strength of the metal. Before the Brooklyn Bridge, the individual wires that make up the rope were made from iron. Roebling developed stronger cast steel wires for the Brooklyn Bridge and spun them on site to make them of sufficient length.

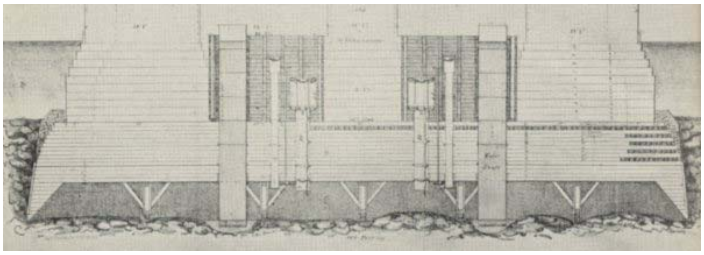


Cables

Four 15 3/4-inch cables are the backbone of the bridge. The decision to use steel instead of standard iron wire was a revolutionary one. Steel was regarded as a suspect material, not yet proven over time as iron was. In fact, at the time of the construction of the Brooklyn Bridge, the use of steel in any structure in Great Britain was illegal. Steel would be vindicated as a tensile material in the Brooklyn Bridge, and at the same time, as a compression material in the St. Louis Bridge.

The four cables support a dead weight (the deck and suspenders) of 13,240 kips—3,410 kips per cable (A kip is a unit of force equal to 1000 pounds.) Each cable has an ultimate strength of 24,600 kips, but the maximum load on a single cable rarely exceeds 6,000 kips. This gives us a present-day factor of safety of about four. The river span is 1,595.5 feet, and the maximum sag over the river is about 130 feet. The length of each supported land span is 930 feet.

Caisson Waterproofing



The towers of the Brooklyn Bridge sit in the East River. In order to begin construction, watertight structures, known as **caissons,** needed to be built to provide a safe place for workers while constructing the bases. In order to ensure that the structure would be watertight, all seams were caulked with oakum; airtight varnish was applied to timbers and the lower three feet were clad in boiler plate inside and out; hot pitch was poured between all the courses of the roof; tin sheath was laid between the fourth and fifth courses of timber; and the entire perimeter of the caissons was wrapped.

In the case of the New York caisson, Washington Roebling knew that the caisson would have to be sunk to a much greater depth to reach stable ground. Because of the increased depth of the caisson, two other safety precautions were also taken: first, the entire inside of the caisson was lined in iron boiler plate to protect against fires, and second, the inside walls were whitewashed to reflect more light.

Student Resource 3.1.2

Roleplay: Caisson Worker

Like most industrial workers of that era, the men in the caissons worked long hours, six days a week, under terrible conditions, for only $2 a day. Only when the Brooklyn caisson reached a depth of 28 feet did management decide that the work was so hazardous that the pay should be raised to $2.25 a day.

It is surprising that men would have been willing to risk their lives in such obviously dangerous circumstances while putting their trust in a new and largely untested technology. Although Washington Roebling was very concerned for the safety of his workers and took all the same risks himself, his attitude was unusual for this era and may well have resulted in part from the continual public scrutiny his project was under.

There was no health insurance during this era, so when caisson workers did begin to suffer from the dreaded “caisson disease” (better known today as **the bends**) they received little more than short-term treatment by the company doctor, and then were simply sent home. If a worker’s injuries were bad enough to make it impossible for him to work, he was out of a job. Aside from the physical risks, working in the caissons was extremely unpleasant. The air was heavy and dank, and the temperature was always at least 80 degrees and often higher. There was a constant stench from the East River mud that covered all the inside surfaces. Roebling’s master mechanic, E. F. Farrington, described the scene in the caissons as one from *Dante’s Inferno.*

Given such terrible conditions, it is no surprise that the men in the caissons quit in droves. Over 2,500 different individuals worked in the Brooklyn caisson from start to finish. Overall, about one in three workers decided to walk off the job, up to 100 a week. What is surprising is that so many were willing to take their places. For every man who quit, at least a dozen were willing to take his place. Most of them were Irish, German, or Italian immigrants so poor and desperate for work that they were willing to take any risk for almost any pay. Many were described as thinly clothed and undernourished, which made their chances of enduring the conditions in the caissons even worse.

Only when the cases of the bends began to occur with increasing frequency in the Manhattan caisson did the workers attempt to improve their circumstances by going out on strike. On May 8, 1872, the entire workforce of caisson men refused to go to work. They stood out on the street nearby and demanded $3 for a four-hour day, because the work had become so dangerous. The bridge company offered $2.75 a day, but that was rejected by the strikers, and a worker who tried to break through their lines was badly beaten.

Your Role

You are a caisson worker. You’re glad to have a job at all—there are always a dozen guys lined up to take your place if you miss a day. But this is getting ridiculous. It’s so disgusting working in the caisson, and it’s really dangerous. Surely the bridge company can afford to pay a little more? Men die down here, after all! $3 a day isn’t too much to ask for.

Student Resource 3.1.3

Roleplay: Bridge Company Official

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Your Role

You are a director at the bridge company. You can't believe the workers actually refused to work. This has never happened before! The company's done a lot to try to make things safe, but building the bridge is a dangerous job—there's no getting around it. Those guys are lucky to even be working on the bridge. The pay's good compared to what else they could be making, and can't they see the line of new guys who would start in a second? But, you can admit it is dangerous, unpleasant work. You've offered $2.75, a 75 cent increase per day. That's as high as you're will to go. Let's see how that goes. If they don't like it, tell them they can take a 25 cent increase or get fired! There's always the new guys waiting outside…

Student Resource 3.1.4

Roleplay: Unemployed Immigrant

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Your Role

You are an unemployed immigrant. It’s so hard to find work. You spent everything you had just to come to America. Your whole family is here, and they’re depending on you. If you don’t find work soon, you don’t know how you’ll keep everyone fed. If only you could get a job working on the Brooklyn Bridge! You’ve heard that it’s dangerous and unpleasant, but it would be worth it just to have a job. You’ve heard that the workers aren’t happy with the conditions and have threatened to stop work if they don’t get a pay raise. Maybe this is your chance. You’re ready to get that job if they don’t want it. $2 a day is way better than nothing.

Student Resource 3.1.5

Roleplay: General Public

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Your Role

You are a concerned citizen. Be creative in picking your character. Choose to be wealthy, middle class, working class, or poor. You can choose to nasty or nice, but in general remember that there was a prevailing philosophy of Social Darwinism during this era. Watch the strike closely, and offer your opinion as a member of the public.

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Building the Brooklyn Bridge

Teacher Resources

Resource	Description
Teacher Resource 3.1.1	Activity: 19th-Century Commercials
Teacher Resource 3.1.2	Background Information: Brooklyn Bridge Construction

Teacher Resource 3.1.1

Activity: 19th-Century Commercials

Directions for the Class

Cut up the list of 19th-century inventions below into strips. Group students into pairs, and have them select an invention at random. If you like, you may give them a minute to trade their inventions. Their job is to create a 15-second commercial selling their invention to an amazed 19th-century audience. Their commercial should include a catchy slogan and a description of how the invention will make a difference in lives of the consumer.

Inventions

1846 Isaac Singer patents a **sewing machine** in the United States.

1857 George Pullman invents the **Pullman Sleeping Car** for train travel.

1861 Dr. Richard Gatling patents the first **machine gun**.

1864 Louis Pasteur develops **pasteurization**.

1866 Alfred Nobel invents **dynamite**.

1868 J. P. Knight invents **traffic lights**.

1874 Joseph Glidden perfects **barbed wire**.

1876 Alexander Graham Bell patents the **telephone**.

1882 Schuyler Wheeler invents the **electric fan**.

1883 James Ritty and John Birch patent the first working mechanical **cash register**.

1885 Karl Benz invents the first practical **automobile** powered by an internal-combustion engine.

1886 Josephine Cochrane invents the **dishwasher**.

1886 Dr. John Pemberton invents **Coca-Cola**.

1888 A. Eugen Fick and Edouard Kalt independently begin prescription of **contact lenses**.

1892 Jesse W. Reno patents the **escalator**.

1895 The Lumiere brothers unveil the **cinematographe**, using it to film and present a projected motion picture to a paying audience of more than one person for the first time.

1898 Conrad Hubert invents the **flashlight**.

Teacher Resource 3.1.2

Background Information: Brooklyn Bridge Construction

After 60 years of political, financial and technical discussions (including a six-lane tunnel proposal in the 1830s), John Roebling's plan for a bridge crossing the East River was approved, the New York Bridge Company was formed, and, in 1869, construction of the bridge finally began.

The bridge was built over a period of 14 years in the face of enormous difficulties: Roebling died as a result of an accident at the outset. A fire in the Brooklyn caisson smoldered for weeks. Roebling's son, Washington, who took over as chief engineer, suffered a crippling attack of the bends during the construction of the Manhattan caisson (yet continued to direct operations, sending messages to the site via his wife, Emily). After the towers were built, a cable parted from its anchorage, killing two people. A fraud was also perpetrated by the cable contractor.

In the end, John Roebling's prediction that the promenade above the deck would be "of incalculable value in a crowded commercial city" was justified, together with his perhaps most noted statement, claiming that "the great towers...will be ranked as national monuments...As a work of art, and a successful specimen of advanced bridge engineering, this structure will forever testify to the energy, enterprise, and wealth of that community which shall secure its erection."

On May 24, 1883, with schools and businesses closed, the Brooklyn Bridge, also referred to as the Great East River Bridge, was opened. Scores of people attended the spectacular ribbon-cutting event. Over 100 years later, its renowned beauty and stature are still admired by many New Yorkers and tourists alike.

AOE POE Integrated Curriculum Unit: Bridge Builder

Lesson 3.2

Principles of Engineering

Bridge Blueprints

In this lesson, students are given the assignment for their culminating bridge-building project. Students will design a bridge that fulfills the given design constraints, create a computer model, and then analyze their design using the modeling software.

This lesson is expected to at least two class periods, as well as additional days for research and computer modeling.

Lesson Framework

Learning Objectives

Each student will:

- Mathematically analyze a simple truss to determine types and magnitude of forces supported in the truss.
- Design a model bridge to support the greatest amount of weight per gram of bridge mass.
- Prepare and present a mathematical analysis of a truss design as part of a 5-minute oral presentation about their bridge design.

Academic Standards

- Students will develop an understanding of the attributes of design. (ITEA Standards for Technological Literacy, Standard 8)
- Students will develop an understanding of engineering design. (ITEA Standards for Technological Literacy, Standard 9)
- Students will develop the abilities to apply the design process. (ITEA Standards for Technological Literacy, Standard 11)
- Students will develop the abilities to use and maintain technological products and systems. (ITEA Standards for Technological Literacy, Standard 12)

Assessment

Assessment Product	Assessment Criteria
Bridge drawings and stress analysis done in MDSolids	None provided at this time
Oral presentation on bridge design	None provided at this time

Prerequisites

- Lesson 2.1
- Working knowledge of MDSolids software

Instructional Materials

Teacher Resources

- Teacher Resource 3.2.1—Answer Key: Truss Designs

Student Resources

- Student Resource 3.2.1—Research: Truss Designs
- Student Resource 3.2.2—Design Brief: Bridge Project

Equipment and Supplies

- MDSolids software
- Autodesk Inventor software
- Computer lab

Lesson Steps

Step	Min.	Activity
		CLASS PERIOD 1
1	**10**	**Introduction: Bridge Project** Pass out Student Resource 3.2.2, the Bridge Project design brief. Have each student select a partner, and then explain the bridge project to the class.
2	**varies**	**Research: Trusses** Before they begin their bridge design, pass out Student Resource 3.2.1, the Truss Designs Research handout. Have students conduct some research on the different types of truss designs commonly in use. Have students find at least five different truss designs, describe which trusses are in tension or compression, and any particular advantages or disadvantages that particular truss design has.
3	**varies**	**Pair Work: Bridge Design** Give students time in class to work on their designs. Each pair should create a computer model of the sides of the bridge using MDSolids, calculate the forces at each joint, and submit a printout of the model and results of the analysis. Students should also create a drawing of the bridge in Autodesk Inventor and submit a side elevation, plan view, and front elevation.
		CLASS PERIOD 2
4	**50**	**Presentations: Bridge Designs** When everyone has completed and analyzed their bridge design, have each pair give a short oral presentation. In the presentation, students should display a diagram of their bridge and describe what type of truss design they selected and why they chose to use this particular design. Have the class vote on a favorite design.

AOE POE Integrated Curriculum Unit: Bridge Builder

Lesson 3.2

Bridge Blueprints

Student Resources

Resource	Description
Student Resource 3.2.1	Research: Truss Designs
Student Resource 3.2.2	Design Brief: Bridge Project

Student Resource 3.2.1

Research: Truss Designs

Directions: *Research each of the three truss designs named below and two of your own choosing. Draw a diagram of the truss design, label which trusses are in tension and compression, and describe any particular advantages or disadvantages of each design.*

Warren Truss

Pratt Truss

Howe Truss

_____

_____

Student Resource 3.2.2

Design Brief: Bridge Project

Purpose

Scale models of bridges can provide us with clues about the stresses and how the structure will behave under those stresses.

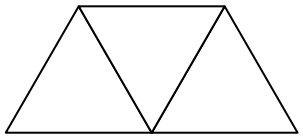
Using the skills you've developed with trusses and bridge design, design and construct a bridge made from balsa wood. Working in teams of two, design and build a truss bridge that will withstand the largest load while minimizing the bridge's weight.

Equipment

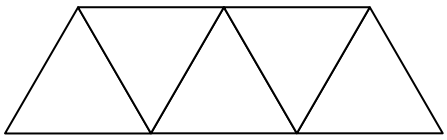
- Balsa wood
- Yellow carpenter's glue
- Cardboard
- Wax paper

Design Constraints

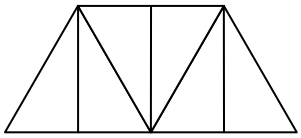
- Bridge must use a truss design.
- Models will be constructed using balsa wood and commonly available yellow carpenter's glue.
- Decorative painting is allowed, but no paint or coating can be applied to the joint between pieces.
- Dipping, soaking, or painting to add strength is not allowed.
- Sides will be trusses, each containing at least two panels, as shown in figures to the right.
- Length of span is 300 mm.
- Height will be less than 100 mm.
- Distance between truss sides will be greater than 55 mm and less than 75 mm.
- The roadway deck will be continuous, without holes or gaps.
- No part of the bridge shall be more than 10 mm below the top surface of the roadway deck.
- A load plate 50 mm by 50 mm will be used to load the structure at mid-span. The roadway deck should be strengthened or reinforced at the load point.



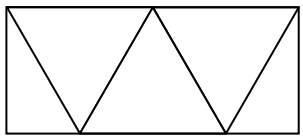
Two-panel truss



Three-panel truss



Modified two-panel truss



Inverted two-panel truss

- There must be an opening in the top of the structure through which the load plate can pass to bear on the roadway deck. A 10 mm hole through the roadway deck will be provided for a load piston to enter.
- Models cannot be made from one solid piece.
- The supports will be 12 mm wide at each end and will not support thrust forces developed by the model. Arch bridges cannot be used.

Project Requirements

Each team will

1. Create a computer model of the sides of the bridge using MDSolids and calculate the forces at each joint. Submit a printout of the model and results of the analysis.

2. Create a drawing of the bridge using Autodesk Inventor. Submit a side elevation, plan view, and front elevation.

3. Use a plot of the plans as a template for constructing the bridge.

4. Load test the bridge to failure.

Bridge Evaluation

1. Each model will be weighed.

2. Each model will be load tested to failure.

3. Models will be ranked based on an efficiency number. The efficiency of each model will be calculated from the following equation:

Efficiency = Maximum Load (grams)/Model Weight (grams)

AOE POE Integrated Curriculum Unit: Bridge Builder

Lesson 3.2

Bridge Blueprints

Teacher Resources

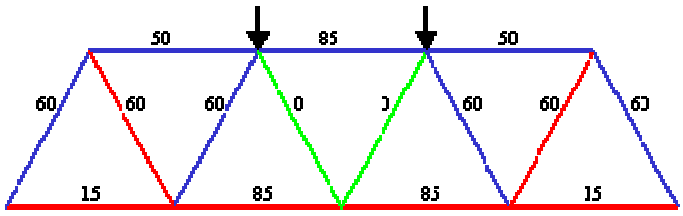
Resource	Description
Teacher Resource 3.2.1	Answer Key: Truss Designs

Teacher Resource 3.2.1

Answer Key: Truss Designs

Directions: *Research each of the three truss designs named below and two of your own choosing. Draw a diagram of the truss design, label which trusses are in tension and compression, and describe any particular advantages or disadvantages of each design.*

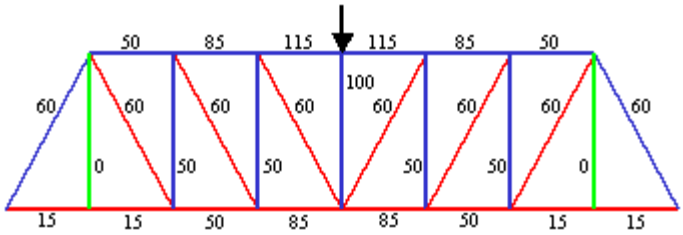
Warren Truss



Red represents tension, blue represents compression, and green is no load.

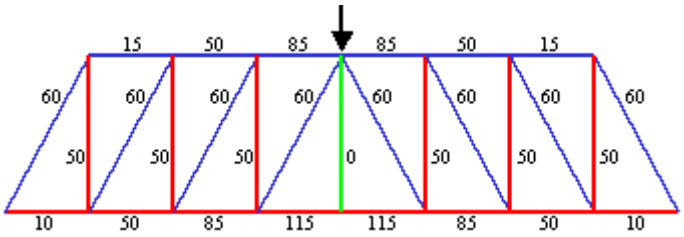
The Warren truss is perhaps the most common truss used for both simple and continuous trusses. For smaller spans, no vertical members are used, lending the structure a simple look. For longer spans, vertical members are added, providing extra strength. Warren trusses are typically used in spans of between 50 and 100 meters.

Pratt Truss



The Pratt truss is identified by its diagonal members, which, except for the ones at the very ends, all slant down and in toward the center of the span. Except for those diagonal members near the center, all the diagonal members are subject to tension forces only, while the shorter vertical members handle the compressive forces. This allows for thinner diagonal members, resulting in a more economic design.

Howe Truss



The Howe truss is the opposite of the Pratt truss. The diagonal members face in the opposite direction and handle compressive forces. This makes it a very uneconomical design for steel bridges, so it is rarely used.

AOE POE Integrated Curriculum Unit: Bridge Builder

Lesson 3.3

Principles of Engineering

Opening Day

In this lesson, students build and present their culminating projects. Their designs are tested for strength and measured for fulfillment of design constraints.

This lesson is expected to take two class periods (plus more for building models in class, if time allows).

Lesson Framework

Learning Objectives

Each student will:

- Apply knowledge of compression and tension forces to design and build a balsa wood truss bridge.

Academic Standards

- Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and sound reasoning. (ITEA Standards for Technological Literacy, Standard 10)
- Students will develop an understanding of and be able to select and use transportation technologies. (ITEA Standards for Technological Literacy, Standard 18)
- Students will develop an understanding of and be able to select and use construction technologies. (ITEA Standards for Technological Literacy, Standard 20)

Assessment

Assessment Product	Assessment Criteria
Truss bridge model	None provided at this time

Instructional Materials

Teacher Resources

- None

Student Resources

- Student Resource 3.2.2—Design Brief: Bridge Project

Equipment and Supplies

- Balsa wood
- Carpenter's glue
- Cardboard
- Wax paper

Lesson Steps

Step	Min.	Activity
		CLASS PERIOD 1
1	**5**	**Lesson Springboard** Remind students of their designs from Lesson 3.2. Announce and/or display the designs that were the favorites.
2	**varies**	**Construction: Bridge Building** Have students build a bridge based on their design. Demonstrate the basic building techniques using the balsa wood and glue. You may allow students to use different materials, but you will need to determine the density or mass of those materials so that students can make the appropriate calculations. Provide multiple class periods for building. You may allow students to build on their own time if they choose.
		CLASS PERIOD 2
3	**30**	**Competition: Opening Day** Test the bridges' strength.
4	**20**	**Lesson Closure: Reflective Writing** Now that students have seen how their bridges performed, ask them to reflect on their design decisions and construction process. Have students write one or two paragraphs explaining their design and construction, what they were satisfied with in their execution, what they would have changed, and why.

AOE POE Integrated Curriculum Unit: Bridge Builder

Lesson 3.3

Opening Day

Student Resources

Refer to Student Resource 3.2.2—Design Brief: Bridge Project for this lesson.

AOE POE Integrated Curriculum Unit: Bridge Builder

Lesson 3.3

Opening Day

Teacher Resources

There are no teacher resources for this lesson.