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The East River Bridges of New York: An Expression of American Industrial Expansion

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by John Buell

Objectives

Introduction

This unit is designed to be taught in U.S. History II. U.S. History II is a required course for graduation which covers U.S. history from the end of the Civil War to the end of the 20th Century. The unit will form the main focal point of study of industrial America at the end of the 19th Century. It will culminate with a field trip aboard a schooner down the East River for a close look at the bridges that will be the object of our study. With some expansion and alteration this unit could also form the basis for a half year interdisciplinary course to be team taught with another teacher who would cover the mathematical and engineering aspects of the topic in greater detail. The great challenge of teaching a survey course like U.S. History II is to cover the vast amount of material required while still going into enough depth to make the subject meaningful and to engage a wide range of skills beyond simple retention and repetition of information. To accomplish this it is necessary to choose certain key focal points to be considered in some detail that pull together and illustrate a range of important curricular issues. These focal points may be important individuals or groups, key events, geographic locations or even trends. Each focal point should allow students to attain a deeper level of understanding of a range of interconnected historical issues. Using this method a survey course can cover the significant elements of a large span of history without sacrificing the development of skills that are the critical to the study of history.

The study of the design and building of New York City bridges in the late 19th Century accomplishes this end by pulling together numerous threads which run through American history at the peak period of industrial growth. It incorporates the issues of urban growth and the resulting changes in transportation needs that provided the impetus to build more bridges of higher quality. It includes consideration of innovations in industrial processes and the introduction of new materials for building such as the mass production of steel and the introduction of steel cable. The availability of these materials combined with the needs of an urban industrial society led to exciting innovations in design. The issues of immigration, social class and the experience of workers in the new industrial economy are also a critical part of the story. These patterns of innovation, invention, immigration, and social change were repeated throughout American society during this era.

The city of New York represents an ideal location upon which to focus an historical study on bridges for a number of reasons. No other American city grew faster, had a larger immigrant population or had a greater need for colossal bridges. Indeed by the late 19th Century bridges were critical to the city's continued growth and development. All this was a direct result of geography which must be fully appreciated if one is to understand the development of New York as a major urban center. New York's founding and rapid growth were a direct result of its fabulous harbor and the surrounding waterways. The influence of geography on history becomes therefore yet another key element covered in this unit. It will develop a deeper understanding of geography which is often given short shrift in survey courses when the pressure is always to rush on to the next historical event. Geography is in fact one of the primary factors determining the design and method of construction of a bridge.

New York also makes a good choice for a unit on bridges because of its proximity to New Haven which allows for the use of resources that are unique to the Sound School where I teach. The Sound School is a Regional Vocational Aquiculture Center which focuses much of its curriculum on the study of the marine environment. The school owns and operates a fleet of small vessels (both sail and power) which can be used by any qualified teacher within his curriculum. In addition, the school makes regular use of the Quinnipiack, a 91 foot schooner which is owned and operated by Schooner Inc. and is docked at the school's pier. Schooner's offices are located on Sound School's campus which makes coordination and planning of elaborate long range trips much easier and Sound School's budget has an automatic allotment each year for the use of the Quinnipiack so funding is rarely a problem. These circumstances present an opportunity for students to travel to New York and view the East River bridges from the deck of the schooner. This vantage point allows for an excellent perspective on the structure of each bridge and allows for an easy way to compare them as each is viewed in succession. In addition, Sound School's powered scows (which are large enough to carry an entire class) can provide excellent platforms to view the variety of bridges in New Haven over the Mill and Quinnipiac Rivers. Such a field trip prior to the culminating trip to New York would be useful to get students to begin consideration of issues of geography, purpose and design in bridge construction and would also provide a valuable point of comparison with New York.

The Industrial Revolution and New York's Bridges: Background Information

Any general study of the 19th and early 20th Centuries in American history must consider the substantial impact of industrialization. Beginning in the early 19th Century with the development of mass production in textiles and powered by steam engines burning coal, the Industrial Revolution was set to begin a new phase by the end of the Civil War. This Second Industrial Revolution was based on three major developments all of which are central themes in this unit. The most important of these and one in which bridges played a critical role was the completion of modern transportation and communication networks to allow the high volume flow of goods. Second was the development of electricity as a more flexible source of power for industrial machinery but which also proved especially important in new forms of urban transportation. The third development was the beginning of the application of science to industry and to the creation of new and improved materials and products which were utilized in the new designs of ever larger bridges.

Urban Growth

Since it began, the Industrial Revolution led directly to rapid urban growth that accelerated as the 19th Century wore on. Improved farming methods and increasing farm mechanization combined with the draw of industrial jobs led to a steady migration from rural to urban areas. When the Civil War began, only one American in five was living in a city. By 1915, half the U.S. population lived in cities. While the nations rural population doubled over this period, the urban population grew more than 700 percent. The new urban industrial economy led to a self generating growth in which a growing pool of cheap and available labor encouraged the formation of more and more industrial enterprises. New York's growth during this era was based not only on these new economic forces but also on the fact that the city was already a great center for trade and commerce before the Industrial Revolution began. This was because the city was founded on the site of the best natural harbor on the North American continent. To be successful as a port, a harbor needs to meet several criteria. It should be large and deep enough to accommodate a significant number of ocean going vessels and provide protection from seas and wind in all directions. It must also have easy access to the open ocean. Most importantly, especially in the pre-industrial age, a successful port needed to have a navigable waterway to give access to the hinterland so that trade goods could be easily transported to the port for transhipment. A look at a map (or better yet a nautical chart) reveals that New York meets all these criteria extremely well. Located on an island in a deep bay near the mouth of the Hudson river with excellent protection from the open sea provided by Long Island and Staten Island it is easy to see why it became so successful as a port. This advantageous geography however had a great influence on the pattern of growth of the city and created a unique set of concerns in which bridges had to play a role.

Even at the start of the 19th Century New York's leaders were well aware of their city's potential for growth. In 1807 the state legislature appointed a special commission "to lay out streets, roads, public squares of such extent and direction as to them shall seem most conductive to the public good." The result was the "Commissioner's Plan," an eight foot long map which laid out the now familiar grid of streets and avenues onto Manhattan Island all the way up to 155th Street. For a city of about 100,000 that only just extended as far north as Greenwich Village it was an audacious plan indeed. The commissioners acknowledged as much in the accompanying report stating that "it may be the subject of merriment that the commissioners have provided space for a greater population than is collected at any spot this side of China." It certainly seemed at the time that this was all the planing the city would ever need and yet by the end of the century the plan was filled to the limit and beyond.

Another fact that the Commissioners did not foresee was that New York's growth was not going to be limited to the Island of Manhattan, but would in fact extend well into Long Island before even half of their plan was fulfilled. Rapid growth in Brooklyn right across the East River from the commercial center of New York was made possible by the introduction of the steam ferry in 1814. The Fulton Ferry took only twelve minutes to travel from the relative peace of Brooklyn Heights to downtown New York. By comparison the trip up to Greenwich Village at the northern edge of the city took an hour by foot or omnibus. For the next twenty years until the introduction of steam railroad service up 4th avenue, transportation technology provided commuters who could afford it a more attractive option in Brooklyn than uptown Manhattan. This was more than enough time for Brooklyn to get a good start down the path of urbanization as the industrial economy began to heat up.

The first half of the 19th Century therefore, was a time of unprecedented growth for both New York (which before 1898 included only the island of Manhattan) and Brooklyn. In 1825 the Erie Canal was completed which further established the city's status as the nation's premier port. Now mid-western produce that may have traveled down the Mississippi to New Orleans, down the St. Lawrence to Montreal or down the Delaware to Philadelphia all came to New York. The city's population grew from 123,706 in 1820 to over 800,00 in 1860. In that year a new planning commission was appointed to lay out streets north of 155th Street. Brooklyn's growth was even more dramatic. In 1820, seven years after the Fulton Ferry went into service, the former village of Brooklyn had grown to 7,000 people. By 1860 the city had annexed Greenpoint and Williamsburg to become the third largest city in the country (after New York and Philadelphia) with a population of 267,000. By this time it was apparent that the ferries were not up to the task of connecting these two burgeoning populations; a bridge was needed. The Industrial Revolution, having created the need for a bridge, would also provide the solution.

Innovations and Inventions

Part of the solution would be steel, a material that would transform the building of large structures. The Second Industrial Revolution can aptly be called the beginning of the age of steel. New methods that would revolutionize the production of steel, the Bessemer process and the open hearth method, were developed in Europe in the 1850s and copied in America by the end of the 1860s. Steel, which was harder and stronger than iron, could now be mass produced at a far lower cost than ever before. Steel provided the bridge builder with a material that was extremely versatile in that it was strong in both tension and compression and yet comparatively light. Because it was so much stronger, steel allowed bridge builders to be more economical since less of it was needed. Innovative designs such as the suspension bridge that had been used in bridges of impressive size with stone and iron could now be fully utilized on an even grander scale. Even well established forms such as the arch and the truss could be utilized to their full potential. Examples of all of these can be seen in the East River bridges most of which were built just as steel was coming into its own. Another innovation that is perhaps even more central to the story of the East River bridges was the development of wire to be used in construction and for other industrial purposes. John A. Roebling who was later to be the designer of the Brooklyn Bridge, was the first in the United States to make iron wire rope which was laid up and twisted like that which was made from natural fiber. Based on articles he had read in a German periodical, it proved to be far stronger and longer lasting than the hemp cables it initially replaced. It was this type of wire rope - by then made of steel - that was used in the suspenders and stays of the Brooklyn Bridge. Roebling was also a pioneer in the use of wire to make the cables to provide the primary support in a suspension bridge. His method of "spinning" the cables in place, with the wires laid up straight in parallel and then wrapping them in a skin of soft outer wire is still in use today. Inventions and innovations such as these were essential ingredients in the Industrial Revolution as they were repeated in a variety of fields and industries.

One final element essential to the Industrial Revolution which played an important role in the construction of the East River bridges was development of new forms of power. Without steam power, which had helped to bring about the First Industrial Revolution, the building of the Brooklyn Bridge would not have been possible. Steam engines were required to lift the stone blocks for the towers, power the air compressors for the pneumatic caissons, carry the wires for laying the cables and run the cable cars used on the bridge when it was first completed. By the time the second East River bridge - the Williamsburg Bridge - was under construction in 1897, all of those tasks were powered by electricity. By 1908 (five years after the completion of the bridge) the electric powered cars of the Brooklyn Elevated System were running on the bridge. Electricity continues today as the source of power for urban mass transit.

Immigration and Issues Facing Workers

One of the most significant effects of the Industrial Revolution was the creation of a new social class of workers. The people who provided the labor for the new economy were usually poor and possessed few skills as few were required for most industrial jobs. They worked long hours at low pay often under appalling conditions. Increasingly viewed by their employers as merely cogs in the machinery of production, they had few rights and no effective way to fight for them. Throughout the late 19th and early 20th Centuries, the labor movement in the United States was weak and largely limited to the minority of workers who had skills. Efforts to organize and fight for humane treatment were usually beaten back with help from government which largely served the interests of the employers. To make matters worse the nation during this time had open immigration - a policy which was strongly supported by big business. The result was ever larger numbers of people looking for work which kept wages down and made it even more difficult to organize unions. Over time the working class, especially those without skills, was increasingly made up of the foreign born.

More than any city in the country, New York was a magnet for those arriving from other countries. As the nation's foremost port it was the entry point for over 70 percent of all immigrants many of whom chose to stay in the city. The immigrants came in two great waves, the first occurring in the mid-19th Century and made up mostly of immigrants from northern and western Europe. In 1820, 11 percent of New York's population was foreign born, but by 1860 that proportion had grown to 50 percent representing a total number of over 400,000 people. The largest immigrant group was the Irish who made up half of the foreign born living in New York in 1860.

Facing widespread discrimination in employment and housing the Irish struggled to survive especially in the years around mid-Century when they were just arriving. They were forced to settle in rundown areas inhabited primarily by people of their own nationality. One of the most notorious neighborhoods was just North of City Hall and was known as the Five Points. In the center of that neighborhood stood the Old Brewery, a decrepit old tenement where rooms could be rented for as little as two dollars a month. At one time it contained 1,200 people and was the most densely populated building in the city. Only the least desirable menial jobs were open to the Irish and they felt lucky if they could get a full time job in a sweatshop. When one understands the level of desperation that the immigrant working class faced, one can understand why so many would be willing to endure the horrendous conditions and high risk of working in the pneumatic caissons of the Brooklyn Bridge. By the end of the Century the Irish, having acquired job skills, respectability, and political power, were moving up and being largely replaced by the next great wave of immigration from southern and eastern Europe.

The East River Bridges - Strategies

Urban Growth: Understanding the Need For A Bridge and Establishing the Design Requirements

The main objective of this unit is to encompass these three basic issues of industrialization through lessons that focus on the East River bridges. The first step is for students to understand why the bridges came to be seen as necessary in the first place. 19th Century maps of New York, copies of which can be made from the Yale map collection in Sterling library, are very useful in showing the growth patterns in both Manhattan and Brooklyn. These should be transferred to an overhead so that they can be viewed by the class as a whole. Combined with population data and data on the growing numbers of commuters using the ferries the maps create a compelling picture of urban growth. After listing the basic criteria for a successful port, students should use a 19th Century nautical chart to see how well New York meets each of them. Maps should also be used to calculate commute times based on various forms of available transportation to illustrate the original reason for growth in Brooklyn. Students should use the data and contemporary news accounts of related events such as the freezing of the East River in the winter of 1866-67 to write editorials making the case for a bridge in 1867 and outlining the benefits it would bring to the communities on both sides.

The next step is to assign students the task of establishing the design criteria an East River bridge will have to meet. Using contemporary illustrations (probably best projected on an overhead) students will note the heavy river traffic with numerous vessels that require significant vertical clearance. The maps and illustrations will indicate the distance to be spanned and the significant population density on both shores. These visuals will also reveal that the local topography offers little (especially on the Manhattan side) to provide natural support to a bridge. Students should also consider the volume and type of traffic that a bridge in this location will have to carry. After viewing the illustrations and engaging in a discussion on the various considerations, students will write a request for a design proposal, listing all the requirements an East River bridge will have to meet.

Individual Bridge Profiles

The Brooklyn Bridge - 1883

The story of the Brooklyn Bridge is the stuff of legend and it would certainly by easy to focus the entire unit, if not a good portion of a semester teaching it in all its glorious details. For the purposes of this unit, however, it is only necessary to focus on certain significant elements that illustrate the basic historical trends of industrialization. The design John Roebling proposed that would satisfy the necessary criteria for crossing the East River was a suspension bridge of such size that it would remain the largest of its type in the world for 20 years after its completion. Its essential feature is a single uninterrupted span 1595 feet in length held 133 feet above the water at its highest point with no obstructions to navigation below it. The building of the bridge entailed two great technical challenges which should for the basis for the lessons on this bridge. The first was the building of the colossal stone towers that bear the entire weight of the bridge high enough 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. At 268 feet, the towers were certainly the "most conspicuous features" of the bridge, but the most compelling part of the story of their construction took place out of sight in the pneumatic caissons where the digging of the foundations took place. It is absolutely imperative that illustrations be used when teaching about caissons because they are so fantastic that they literally defy description. The best are contemporary sketches that appeared Harpers Weekly and Scientific American 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. 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. Using the drawings as a guide, the students should 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.

The actual work in the caisson however tells a different part of the story. Like most industrial workers of that era, the men in the caissons worked long hours six days a week under horrendous conditions for only two dollars a day. Only when the Brooklyn caisson reached a depth of twenty-eight feet did management decide that the work was so hazardous that the pay should be raised to $2.25 a day. That men would be willing to risk their lives in such obviously dangerous circumstances while putting their trust in a new and largely untested technology is astonishing. Although Washington Roebling was in fact very concerned for the safety of his workers and took all the same risks himself, his attitude was an anomaly for this era and may well have resulted in part from the continual public scrutiny his project was under. Students should understand that benefits for workers did not exist in this era so when laborers in the caissons did begin to suffer from the dreaded "caissons 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 while the temperature never dropped below 80 degrees and was frequently higher. There was a constant stench from the black East River mud which covered every interior surface. Roebling's master mechanic, E.F. Farrington, describing the scene in the caissons said that "one might, if of a poetic temperament, get a realizing sense of Dante's inferno."

Under such conditions it is no surprise that the men in the caissons quit in droves. Over 2500 different individuals worked in the Brooklyn caisson from start to finish. That comes to about one man in three deciding to walk off the job or about 100 a week. What is surprising is that so many were willing to take their places. For every man who quit there were at least a dozen 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 wage. Many were described as thinly clothed and undernourished which made their chances of enduring the conditions in the caissons less than likely. Students should consider all the circumstances that might lead a recent immigrant to take a such a job and write a first person fictional account of why the decision was made and what the work was like.

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. Although it was the only time there was such a job action during the entire time of construction, the case is illustrative of what workers were up against when they tried to fight for their rights. The entire work force of caisson men refused to go to work on May 8, 1872. They stood out on the street nearby and demanded three dollars for a four hour day because the work had become so dangerous. The bridge company offered $2.75 a day but that was rejected the strikers and a worker who tried to break through their lines was badly beaten. 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. The best way to teach this lesson is with a role play. Students should be divided into four groups: one representing the bridge company directors, one representing the caisson workers, one representing unemployed immigrants looking for work and a final one representing "the public." After hearing a report on the recent cases of caissons disease, the workers group will take a vote to strike and explain their demands. The bridge directors should marshal their arguments and limit any offer to no more than $2.75 per day. The unemployed should make it clear that they are willing to work if the others refuse and should be able to explain their desperate reasons. The public meanwhile may be divided along class lines, but certain attitudes of the time should certainly be present. The basic philosophy of the time on these issues was Social Darwinism which taught that those who would compete for jobs such as those in the caissons are the least fit whose eventual demise would only be a benefit to society as a whole.

The story of the construction of the cables is useful to illustrate the fact that the bridge was being constructed at the very cusp of the age of steel. Students should note that the Brooklyn Bridge is the only East River crossing in which the primary supporting towers are made of stone. In the later bridges steel as a building material had matured to the point that it was the only reasonable choice. The cables, however, were to be made of steel and because it was such a new material the choice of which type of steel became a source of controversy.

Washington Roebling's initial specifications for the cable wire set forth certain strength and performance requirements without specifying how the steel was to be made. The lowest bid came in from his own family's wire company, John A. Roebling and Sons for wire made from steel manufactured with the new Bessemer process (Roebling had sold all his interest in the company to avoid a conflict of interest). Confidence in and knowledge of the Bessemer process was weak enough however that a certain individual with a financial interest in one of the other bidders was able to sow doubt about whether that type of steel was the best for the job. The older more expensive type of steel, crucible steel, was considered the finest grade and was used principally for tools. The contract for the cable wire was awarded therefore to the lowest bidder for crucible steel, but the reality was that no wire manufacturer could produce enough wire produced by the old method in enough quantity at the price quoted. The result was a fraud in which wire that had failed inspection, much of which was in fact made of Bessemer steel, was being switched with good wire and sent to the job site. Fortunately the Chief Engineer discovered the fraud before too much defective wire was spun into the cables, but Bessemer steel (now properly inspected) was the steel used after all.

Student work on this issue could take the form of letters to the editor supporting one or the other types of steel. Those writing in support of the crucible steel should focus on the time tested nature of the method, the high quality of the steel produced and the question of whether the strength of the entire bridge should be dependent on a relatively new cheap mass produced steel. As one editorial writer observed, should the bridge be built with "the cheapest wire, or the best wire at the cheapest rate?" Those writing in support of Bessemer steel should point out that the method had been around for over 20 years, that it had been used extensively in building railroads, that it was the most economical and efficient method of steel production.

The method developed by John A. Roebling for "spinning" the cables in place is another excellent example of the technical ingenuity of this era. Construction of the cables had to be done in place to avoid obstructing river traffic and because once constructed they would be too heavy to pull to the tops of the towers. Pulled by a traveler rope strung over the tops to the towers, a loop of wire was pulled across and over the towers by a big iron wheel which thus laid two wires at a time. As a continuous loop, the traveler rope could carry two of these carrier wheels, one going each direction, at the same time. Like the caissons the system is difficult to describe without illustrations but I have not found any really good ones. The PBS video by David McCauley, *Building Big: Bridges* , has some excellent film footage, however, of this system being used on the construction of the Golden Gate Bridge. The basic method is so good that it is essentially the one still in use for the construction of suspension bridges today.

The Williamsburg Bridge - 1903

Because so many of the great technological leaps were accomplished in the design and construction of the Brooklyn Bridge, examination of the other East River bridges can be - and probably will have to be - shorter. Thus consideration of the Williamsburg Bridge can be limited to two basic themes: the questions of aesthetics which arose as a result of the design of the bridge and the continuing changes brought on by immigration and urban growth. The impact of new technology is significant primarily in the use of the bridge as a link in the newly electrified mass transit system rather than in its construction.

Even before the opening of the Brooklyn Bridge leading citizens of the Williamsburg section of Brooklyn began to push for a bridge that would connect their community to Manhattan. 19th Century maps of New York show clearly how growth in Williamsburg was separate from the early center of Brooklyn due to Wallabout Bay and its surrounding marshland which lie between them. By the late 19th Century the community was made up mostly of upwardly mobile German and Irish immigrants and first generation native born who had been able to escape the tenement slums of Manhattan. Despite being annexed by Brooklyn in 1855, Williamsburg continued to see itself as a separate community with interests more allied to New York. Because of geography, the citizens of Williamsburg realized that the benefits of the Brooklyn Bridge would not easily flow to their community.

In 1897, after more than a decade of delays caused by political and financial problems, a design for a suspension bridge was completed by Leffert L. Buck and construction began. By that time traffic on the Brooklyn Bridge had exceeded all expectations and ferry traffic hadn't diminished at all. To handle this burgeoning growth, the design specifications called for a bridge built with two levels to handle six lanes for trolleys, two lanes for carriages and a pedestrian walkway all of which would require a deck half again as wide as the Brooklyn Bridge. The needs of a growing city and developments in transportation technology were placing greater demands on bridges in New York.

Buck's design was one in which the design specifications were well met, but aesthetic considerations seem to be secondary. For the first time in a bridge of this size steel would be used for the entire bridge, including the towers which would rise 350 feet - 80 feet taller than the towers on the Brooklyn Bridge. As this was one of the first times steel was used in this way, the design of the towers is conservative, relating more to earlier designs such as the Eiffel Tower which was built of wrought iron. The result is a vertical truss with an ungainly profile which compares unfavorably to the monumental gothic towers of the Brooklyn Bridge or the elegant steel frames used in later bridges. Adding to the bridge's aesthetic shortcomings, Buck felt the increased load specifications required a massive stiffening truss which runs 40 feet high the length of the bridge. Finally, the side spans of the bridge is supported in a straight line by steel viaducts rather than suspended from the cables. The result is a span which does not have the continuous graceful curve that is usually associated with suspension bridges. The design for the Williamsburg bridge therefore can be seen as one in which the use of material in a new way and the tremendous load requirements of a growing city led to a bridge which is simply functional - nothing more. Writing in *Scientific American* shortly before the completion of the bridge, one critic stated that one can look over the entire bridge "without finding a single detail which suggests a controlling motive, either in its design or fashioning other than bald utility."

Student work on the Williamsburg bridge should focus in part on this conflict between aesthetics and "bald utility." Photographs of all the East River bridges appear in Sharon Reier's excellent *The Bridges of New York* , but students can probably best judge the comparative beauty of the various bridges when they go to see them. One of the assignments due after the trip should be for students to choose which bridge they think is the most beautiful and which they think is the most ugly and explain why. Discussions prior to the trip as to what factors add to or detract from the beauty of a bridge will serve to provide students with a vocabulary to explain their position. Students should be consider the influence new and relatively untried materials can have on a designer's confidence in his ability to create forms that are graceful as well as functional.

One unquestionably positive effect of technological advances on the construction of the Williamsburg Bridge was the decreased time of construction: only seven years - less than half the time required for the Brooklyn Bridge. Upon completion it played a significant role in the evolution of the immigrant communities in New York. Viewed initially by the German and Irish residents of Williamsburg as bringing the economic benefits of easy access to Manhattan, the bridge was ultimately more important as an outlet for the Eastern European Jewish immigrant community in the overcrowded slums of the Lower East Side. Within the next few decades Williamsburg and adjacent Brownsville became thriving Jewish enclaves while the Germans moved on to Richmond Hill and Jamaica, Queens. Thus, a bridge built in response to urban growth ended up influencing the social and ethnic patterns of that growth.

The Queensboro Bridge and the Manhattan Bridge - 1909

The next two bridges to cross the East River - the Queensboro Bridge and the Manhattan Bridge - were built almost simultaneously between 1901 and 1909. The Queensboro was completed first in July of 1909 and represents the only cantilever type among the major East River crossings. This type of bridge, used most famously in Scotland's Firth of Forth Bridge completed in 1890, is another good example of the innovation in design and use of new materials so common in the Second Industrial Revolution. Students need understand the basic concept of the cantilever design in order to understand why such a design was chosen for that specific location and to understand the controversy surrounding the bridge during its construction. In the cantilever design the overwater span is supported by piers which are kept in balance by the counterweight of the land span. Rigidity is provided by the triangulated members of a truss. The result is a structure that cannot support as long a central span as the suspension type, but has greater rigidity and is usually more economical to built. The design works at the 59th Street location because it makes use of Blackwell Island (today called Roosevelt Island) for central supporting piers. The bridge was also another step forward in the use of new materials as this was the first use of nickel steel which is stronger and lighter than carbon steel. Another innovation was the use of eyebars to connect the primary members with enormous pins weighing 7000 pounds each.

Because the Queensboro does not have a center suspended span, as many cantilever bridges do, the resulting structure is one that has the basic profile of a suspension bridge and one that functions a bit like one as well. The upper chord of the truss is in tension and follows the basic line of a suspension cable as it travels from the top of the towers down to the center of the span and back up again. The towers need to be tall enough to provide the necessary support for the upper chord and are kept in balance by the opposing forces just as towers in suspension bridges. The major difference is in the compression members of the bottom chord which provide support and rigidity that is not present in a suspension bridge.

The choice of a cantilever design for the bridge resulted in controversy as the bridge was nearing completion mostly as a result of a tragic coincidence. In 1907 the Quebec Bridge which was being constructed over the St. Lawrence River in Canada collapsed killing 75 workmen. It was to have been the longest cantilever bridge in the Western Hemisphere and its collapse called into question the use of that type for long spans. Despite the fact that the Queensboro Bridge was shorter by a third, public outcry led to an investigation of its stability and carrying capacity. The investigation did raise some concerns and resulted in the reduction of the number of elevated tracks to two and the removal of some structural material seen as adding too much dead weight to the structure. After the Quebec disaster, cantilever bridges lost favor as a choice for spanning long distances while the suspension type became the standard.

The Manhattan Bridge was completed only three months after the Queensboro, but it makes use of what had become a fairly traditional suspension bridge design. The main structural innovation results from the increasing confidence in this bridge type and in steel. For the first time the towers were built in a two dimensional plane rather than the rigid three dimensional structure used in the Williamsburg Bridge. The result is a tower with far more grace and elegance, yet able to stay erect because of the balance of forces on it. For students it provides a good comparison with the Williamsburg bridge which was completed only a few years earlier and is the only other all steel suspension bridge in the group.

Hell Gate Bridge - 1917

The last of the East River Bridges to be considered in this unit provides an excellent point of comparison with the others not only because of its design, but because it is the only one to be built exclusively for rail traffic.

Designed by Gustav Lindenthal - the designer of the Queensboro Bridge - the Hell Gate Bridge was the longest steel arch in the world when it was completed. As a railroad bridge it was to provide a vital link in what was after all the dominant transportation system of the industrial age. Prior to its completion there was no direct rail link between New England and points south through New York City. Passengers traveling what is now called the "northeast corridor" through New York had to switch from Grand Central Station to Penn Station to continue their journey. Ironically, the bridge was completed just as the automobile began its steady rise to become the nation's dominant form of transportation. Within twenty years of the completion of the Hell Gate Bridge the most important bridge links in the nation's transportation network would carry cars, not trains. Consideration of the Hell Gate Bridge must include a clear understanding of the arch as a basic design form and how it is used in this particular example. In theory, the arch is the strongest and most stable of all the basic bridge types. The curving form of the load bearing structure acts in compression transmitting force to its ends which must be opposed by an equal or greater resistance to keep them from spreading apart. In many cases this resistance is provided by massive abutments or by topographical features such as the sides of a gorge or hills, but it can also be provided within the structure of the bridge by members acting in tension which tie the ends of the arch together. In the Hell Gate Bridge, this service is provided by the bridge deck which is not only supported by the arch above it but also helps it to stand up. This type of arch is sometimes referred to as a tied or bowstring arch. The structure of the arch itself is created by a series of truss panels which provide strength and rigidity without undue weight. This construction utilizing steel members in triangular forms is essentially the same as Lindenthal used in the Queensboro Bridge to provide strength for the cantilever. An important technological advance was the use of carbon steel which provided greater strength for its weight. Thus steel again provided a designer the opportunity to utilize a traditional bridge form on a much larger scale with a far larger load capacity.

Having decided upon the basic form he was to use, Lindenthal wanted to address two issues: how to make the bridge appear strong to the ordinary citizens who would be using it and how to make it aesthetically pleasing. For Lindenthal, who had strongly criticized the lack of aesthetics in the Williamsburg Bridge, the two issues were interconnected. Those features which were to make the Hell Gate Bridge appear strong would also make it attractive. The elements that were added for this purpose, however, are not structurally necessary and do not add to the strength of the bridge. To make the arch look stronger, he increased the distance between the upper and lower chords of the truss at each end. The resulting combination of a flatter curve on top which reverses slightly at the ends and a deeper curve on the bottom creates an image which is strong but also graceful and engaging. Another non structural element added by Lindenthal to his bridge were two massive masonry towers situated at each end of the arch. To the lay person, the towers appear to provide the buttressing that such a massive arch would require. They also give the bridge a striking monumental appearance which provides a counterpoint to the graceful curves of the arch. It recalls a similar combination which is evident in the Brooklyn Bridge.

As a product of the late industrial revolution, the Hell Gate Bridge provides students with a number of issues relevant to this era. One is the question of aesthetics which has already been explored to a certain extent with the Williamsburg Bridge. Industrialization had created the need for new and improved bridges, it had provided new materials and innovations in design to accomplish the task, but the designers and builders of the age often wrestled with the question of whether a bridge needed to do more than provide "bald utility." Students should be able to explain whether Lindenthal's non-structural alterations to the basic bowstring arch form add or detract from the Bridge's essential value. Another issue students need to consider is the role changing technology can play in redefining the importance of a bridge. The invention and mass production of the automobile, both key developments of the late Industrial Revolution, resulted in an entirely new transportation network. While the other East River Bridges have been modified for the automobile, the Hell Gate Bridge cannot be. Students might compare the role of the Hell Gate Bridge to the adjacent Triboro Bridge which was built in the 1930s as a critical link in the region's auto road network. Which bridge is more important in the lives of those who live in and around New York? Is it possible that the importance of the bridges could change if the economics of transportation were to change? There are many who believe, for example, that rail travel may indeed be the answer to many of the nations transportation problems.

Classroom Activities

The most essential activity in the unit will of course not take place in the classroom at all as it will be a visit to the East River to see the bridges themselves. However, a series of lessons and assignments which allow students to explore the issues of Second Industrial Revolution as they relate to the design and construction of the bridges must take place if the full value of the field trip is to be realized.

Lesson Plan: Urban Growth in New York As Seen in Maps

Objectives

Students will identify the patterns of New York City's population growth in the 19th Century and use those patterns to justify the need for bridges at specific locations.

Procedure

The growth of New York can be explored most effectively by viewing contemporary maps as the city grew. The map collection at Yale's Sterling Library is an excellent resource for these maps copies of which can be made on site for one dollar each. Reducing the size at a copy store is important, however, so that the maps can be transferred to overheads so that they an be viewed by the entire class. A list of the best maps will be included below, but they should include at least one - perhaps a nautical chart - which clearly shows the geographic advantages of New York as a port. Others should show both Manhattan and the Brooklyn/Queens end of Long Island so that the growth rates can be compared and the location of the waterways can be noted. I have already noted above the value of considering the Commissioners Plan of 1811 as an indication of the type of growth city planners foresaw before the advent of the steam ferry. At least one map from the second or third decade of the 20th Century will be useful in showing the effects of the bridges on the patterns of continued growth. In order to engage the entire class students should write down their responses to discussion questions for each map as each map is viewed. After students have had time to answer the questions on their own, the teacher can open discussion by asking students to share their responses. Students should correct and amend their answers in their notebooks as the discussion continues. Possible discussion questions:

1. What is included on the map?
2. What areas appear to be thickly settled? How does the map indicate this?
3. Why have people settled in these areas? What are the geographic factors involved?
4. Does the cartographer indicate where he thinks future growth will take place? If so, where is this indicated and did it prove to be accurate?
5. Considering the patterns of growth and geographic factors, what would be a good location for a bridge (or a second, third, etc.)?

More specific questions may of course be necessary for individual maps such as the nautical chart.

Evaluation

Notebooks can be collected or checked to assess student involvement and understanding of the issues raised in discussion.

Lesson Plan: Role Play of the Caisson Worker's Strike

Objectives

Students will demonstrate the dilemmas facing American workers seeking to improve working conditions in the 19th Century.

Procedure

This lesson should take place after students have a good understanding of what caissons are, how they worked and why they were necessary. As indicated above illustrations will be very important in getting these concepts across. Students may even be asked to sketch a caisson on the river bed with the tower rising above it.

Students should be divided into four equal groups representing the following: the bridge company directors, the caisson workers, unemployed immigrant workers, and the public. Based on readings in McCullough (p. 195-199, 303-305) the caisson workers will report on conditions in the caissons and the effects of the "caisson's disease" and will vote to strike for higher pay, demanding three dollars 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 most creative responses can come from the general public who can 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 role play 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 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.

Evaluation

Assessment of student performance should be based in part on the level of each student's involvement in the role play. In addition, the night after the role play each student should write up their position on the strike and explain any changes in position that took place during the lesson.

Lesson Plan: Judging the Value of a Bridge

Objective

Students will use the East River bridges to distinguish factors which add or detract from the value of a particular bridge to the community. Students will judge whether the criteria established for these century old bridges can be used to evaluate bridges of today and those to be built in the future.

Procedure

Prior to the culminating field trip students will compile information in their notebooks on each of the East River bridges. Information will come from lectures with illustrations, assigned readings (see resource list below) and discussion. After seeing the bridges themselves students will pick one of the five bridges as the "best" and defend their choices in writing and discussion. Students should be given the following list of questions which they will answer for each bridge in order to determine their choice:

1. Does the bridge successfully meet the design criteria established at the time of construction?
2. Has it been possible to adapt the bridge to changing needs (new forms of transportation technology, population growth, etc.) over the last century?
3. Was the design of the bridge bold and innovative for its time? Does it still convey that sense of innovation today?
4. Is the bridge visually attractive? Why or why not?

Based on these questions, students should write a persuasive essay in which each of the five bridges is critiqued and the "best" is chosen. Each student will present his/her case to the class on the day that the assignment is due in the form of an oral summary of the essay. After presentations (or during them) discussion will take place allowing students to defend their own positions and critiquing others.

Evaluation

Evaluation should be based on content of notebooks, participation in discussion and the essay. Content of the essays should be evaluated on the degree that the author based his/her choice on specific, well defined criteria.

Conclusion

The idea for this unit came from a boat trip with students down the East River and into New York Harbor. A field trip to view the bridges is an essential element of the unit and critical to its proper completion. The experience of seeing the bridges up close will give students a powerful sense of a different era. The materials used and the designs chosen speak of a time distinct from our own. The stone towers of the Brooklyn Bridge presents an era when all colossal structures were built of stone even while the steel cables indicate changes for the future. The clumsy structure of the Williamsburg Bridge displays a quaint inexperience in building with a new material. The Queensboro Bridge seems absurdly overbuilt for our time when the far greater efficiency of modern designs and materials allow for simplicity and clean lines. The brute strength of the Hell Gate Bridge suggests an era of steam engines when rail travel was dominant. None of this really comes across in photographs and illustrations. Perhaps as interesting as a waterborne visit to the bridges is a walking tour of them. All except the Hell Gate Bridge have walkways that have recently been rehabilitated. From the walkways students can see the intricacies of the detail work and how the elements fit into the overall design. In addition each of the lower three bridges provide excellent views of the other two. The walkways themselves provide a vivid reminder that the bridges were built before the era of the automobile. From the walkways students may also be able to better connect with the human side of the story. Each individual member of these structures was fashioned by workers in the factories of the Second Industrial Revolution. They were constructed by workers many of whom were immigrants or the children of immigrants. The bridges were crossed by the middle class residents of Brooklyn commuting to work in the city's commercial center. They were crossed by immigrants seeking escape from the overcrowded tenements of lower Manhattan.

The joy of history is really the joy of a good story. The bridges of New York tell the story of their time with a powerful eloquence and countless lessons about how we have come to be who we are today.

Resources

Bibliography - those marked with an asterisk would be especially useful for students.

Allen, Oliver E. *New York, New York* . New York: Atheneum, 1990. A general history of New York City which begins with an excellent description of New York Harbor.

Boorstin, Daniel J. and Brooks Mathers Kelley. *A History of the United States Since 1861* . Englewook Cliffs, N.J.: Prentice-Hall, 1990. High school textbook for U.S. History II. Includes a separate chapter on urban growth at the end of the 19th Century.

*Brooklyn Museum. *The Great East River Bridge 1883-1983* . New York: The Brooklyn Museum, 1983 Published for an exhibition of that title, it includes articles on its history and role in American culture and is lavishly illustrated.

Cohen, Paul E. and Robert T. Augustyn. *Manhattan in Maps: 1527-1995* . New York: Rizzoli, 1997. A collection of maps mostly from the 17th and 18th Centuries which show the growth of the city from its founding.

Dupre, Judith. *Bridges* . New York: Black Dog & Leventhal, 1997. A brief history of some of the worlds most important bridges in chronological order with excellent photographs. Includes two of the five East River bridges.

Foner, Eric and John A. Garraty, editors. *The Reader's Companion to American History* . Boston: Houghton Mifflin, 1991. An excellent encyclopedia of American History. Includes useful articles on the iron and steel industry and on the Industrial Revolution.

*Homberger, Eric. *The Historical Atlas of New York City* . New York: Holt, 1994. The history of New York told through maps and illustrations.

*PBS Video. *Building Big:Bridges* . (with David McCauley) 2000. One episode of the four part Building Big series. Overview of the major developments in bridge building in history. Describes all the basic bridge types.

*McCauley, David. *Building Big* . Boston: Houghton Mifflin, 2000. The companion volume to the PBS video series. Excellent source for students to understand basics of bridge building.

*McCullough, David. *The Great Bridge* . New York: Simon and Schuster, 1972. An excellent and very readable history of the building of the Brooklyn Bridge. Includes several pages of useful illustrations.

*Reier, Sharon. *The Bridges of New York* . New York: Quadrant Books, 1977. The only book which includes histories of all five East River crossings as well as every other significant bridge in New York City. Descriptions of current conditions are somewhat dated.

White, Norval. *New York: A Physical History* . New York: Atheneum, 1987. As the name implies, this history focuses on geography, architecture, and urban planning. It has an excellent chapter on the development of the city's transportation networks.

Internet Sites:

*http.//www.nycroads.com/crossings. The most comprehensive site I found on New York City bridges. Includes excellent profiles of each of the East River crossings as well as almost every other link in the city's auto road network.

*nyc.gov/html/dot/htm/get_around/bridges.html. Part of New York City's Department of Transportation web site. Includes a brief description of bridge types and short profiles of the East River bridges as well as updates on current conditions and renovation schedules. Useful for field trip planning.

Maps

The following maps are located in the map room of Sterling Memorial Library at Yale. If you call ahead you can request permission to view most of the maps in the collection. Full size copies can be made for a charge of one dollar each. These can later be reduced at a copy shop to a size that can be transferred to overheads. All of those listed here came out of four folders of New York City maps of the 17th, 18th, and early 20th Centuries. For some I have the exact date and title, but for others I can only give a description and approximate date as the titles did not fit onto the copies. "A Draught of New York from the Hook to New York Town," 1737. A nautical chart showing Upper and Lower New York Bay (inner and outer harbors). An excellent way to demonstrate the geographical reasons why New York early on was a successful port and a growing commercial center.

"A Plan of the City of New York," 1767. Shows the size of New York at the end of the colonial era. Includes the village of Brooklyn and the site of the first ferry before the age of steam.

"Commissioners Plan," 1811. New York's earliest attempt at urban planning. Indicates the prophetic vision that city leaders had early on of the explosive growth that was to come. It is a grid of streets that is almost devoid of anything but the practical concerns of the developer and speculator. One should note that Central Park was not yet part of the plan.

"City of New York," 1833. Shows the growth of the city in the early industrial era. Includes the portions of Brooklyn and Williamsburg that had developed as a result of the steam ferries.

"Topographical Map of the Cities of New York and Brooklyn," 1850s. Shows both cities at the time when the need for an East River bridge became acute. It clearly shows that growth from the original city center was as extensive in Brooklyn as it was in Manhattan.

Map of the vicinity of New York, 1990s (Title and date did not make it onto the copy). Shows the region after the completion of the Brooklyn Bridge, but prior to the completion of the other bridges. Useful for illustrating the need for a bridge to Williamsburg and for seeing the beginning of growth in Queens.

"Rand McNally & Co.'s New Handy Map of New York City," 1910. All the East River spans are here except for the Hell Gate Bridge. The city's transit system is represented including the new subway, the elevated lines and the regular railroad routes. Inset shows growth of greater New York.