BRIDGE CURRICULUM

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Teacher's Background

Lesson Plans

BRIDGE CURRICULUM

Project Overview

This curriculum is built around the **Project #3: *Bridge***. Student engineers with the Rice University Chapter of EWB-USA have been working on projects in the community of El Panama near Jinotepe, Nicaragua. During the team's first visit to the community in March 2004, the community members expressed the need for a pedestrian bridge across the Aragon River to allow for safe crossing during the rainy season. The river, during high flow periods, separates the community from schools, jobs, and emergency medical care that can only be found in Jinotepe.

After obtaining EWB-USA approval for this project and acquiring the necessary surveying skills, the team returned to El Panama to conduct a detailed topographic survey of the future bridge site. The members of the team have completed a preliminary steel truss design for the pedestrian bridge. In the coming months, the team will be working to optimize and finalize the bridge design.

Curriculum Connections

Science:

- Structures
- Geology/topography
- Soil Analysis
- Scientific Method

Math:

- Calculation skills
- Two and three dimensional geometry
- Graphing
- Budgeting
- Estimation

Social Studies/History

- Climate/geography
- Flooding and its social implications
- Daily life in a developing country
- Sustainability
- Collaboration of Stakeholders

SCIENCE

Assessment

Middle School

Structures are only as strong as the soil they're built on, you will be experimenting with various types of soil (sandy, clayey, rocky) to find out which material is most likely to support a heavy bridge and research bridge construction and soil types based on recommended websites.

Materials:

- White paper plates
- 3x5 cards
- At least four Styrofoam cups each with four different types of soil (sandy, clayey, loam, etc.)
- 1/4 cup measure
- Water
- Liquid dropper (optional)
- Pencils
- Straws
- Drawing paper
- Magnifying glasses (or microscopes if available)

Procedure:

1. Ask students whether they would recommend building a bridge on sand or on rock. Ask them to list their reasons, and put the reasons on the board.
   - **Explain:** Students should understand that rock provides a solid foundation for construction, where as sand is likely to shift. It's not always possible to choose the soil you'll build on, but it is always important to know what kind of soil you are building on.
2. Break students into groups, and provide each group with paper cups filled with soil samples, quarter cup measures, containers of water with straws, magnifying glasses, plain white paper plates, drawing paper, and pencils. Have students conduct the following activities and note their findings:
   - Pack the soil tightly in your cup, and turn the cup over on a paper plate. Gently pull the cup up (as you would when building a sand castle). Did the soil stay in place, or did it collapse? Which soil sample holds its shape the best? Based on your findings, which type of soil would make the best foundation for a bridge?
   - Examine particles of soil under a magnifying glass (or a microscope if available) and sketch what you see. Are there differences between the soil that holds a shape and the soil that doesn't? What are the differences?
   - What will happen to the soil samples if they get wet? Measure a quarter cup of each soil onto a separate paper plate. Add water to the samples, drop by drop. When the soil sample looks shiny, use a 3x5 card to cut the sample in half. When the two halves seep back together again, the sample is saturated. How many drops of water does it take to saturate each sample? What happens to the soil when it's saturated? Given what you've learned, which soil would be least likely to collapse in the event of floods? Which would be most likely to collapse?

Extensions: Many structures solve the problem of shifting soil by placing concrete foundations into the soil to provide a solid material on which to build. Assign the class the job of finding and photographing or drawing local structures (such as decks, bridges, piers, etc.), that were built using concrete foundations.

High School

Expand the activity by taking a trip to a local bridge site. Collect soil samples from around the bridge's foundations, and analyze them. If possible, seek out information on the web or from primary sources regarding the actual soil analysis taken when the bridge was built. What were the issues raised at the time of construction? How were those issues managed? Invite an engineer from a bridge design firm to present to the class.

Elementary School

Simplify the middle school activity by having the students attempt to build with dry sand, and discuss what happens. What would make it easier (add water)? Have students add varying amounts of water to sand, and attempt to build. Is it possible to have too much water? What would happen if you built a bridge on sand dunes? What would happen if it rained?

Design

Middle School

Topography of the land is an important factor in determining the siting and placement of a bridge. In this activity, groups of students will use clay and other materials to design the topography of a river and its banks and design bridges made of simple materials (Popsicle sticks, string, etc.) to cross the river. Each group will display its bridge and describe obstacles and how they were overcome.

Materials:

- Four pieces of cardboard
- Topographic building materials (plasticene, sand, gravel, rocks, etc.)
- Bridge building materials (Popsicle sticks, strings, toothpicks, gumdrops)
- Drawing materials
- Handout #1: Simple Topographic Mapping
- Handout #2: Topographic Map

Procedure:

1. Explain to the class that a topographic map shows the heights of landforms. This is very important for bridge building, since it's critical that bridges are level across their span, even when the landforms on either side of the water they cross are of different heights.
2. Hand out the simple topographic mapping handout, and go over it with the class. Answer the questions together.
3. Break the class into three groups, and give each group a piece of cardboard and building materials. Assign each group the task of creating a three dimensional landscape out of the various building materials. Each landscape should include hills, valleys, and a "river" to cross.
4. Have groups pass their landscapes to the group next to them, and have each group create a topographic map of another team's landscape. Based on their map, have them create a 2-D design of a bridge to cross the "river." They should take into account the differences in height between the shores of the river, and come up with a good way to build a bridge that will be level across its span.

5. Have teams pass the landscapes, maps, and designs to the third group. Have the third group actually build the bridge based on the second group's work. Was the map accurate? Could the design be implemented?
6. Using Google Maps/Terrain & Satellite images, look up your own area and/or areas the students are familiar with.
7. Have the teams make a simple topographic diagram of a section of the classroom showing the spacing of desks, bookcases, etc. and relative heights.
8. Discuss the process with the class. What was easy? What was difficult? Which issues came up when information was traded from group to group?

High School

Expand the activity by having students use a real topographic map of the area in Nicaragua (Handout #2), and build a scale model of the local gorge or river. Have students write up a report on the challenges created by the topography, and suggest a real-world solution. Use the USGS site on "how to read a topographic map" to support this activity: egsc.usgs.gov/isb/pubs/booklets/symbols/.

Elementary School

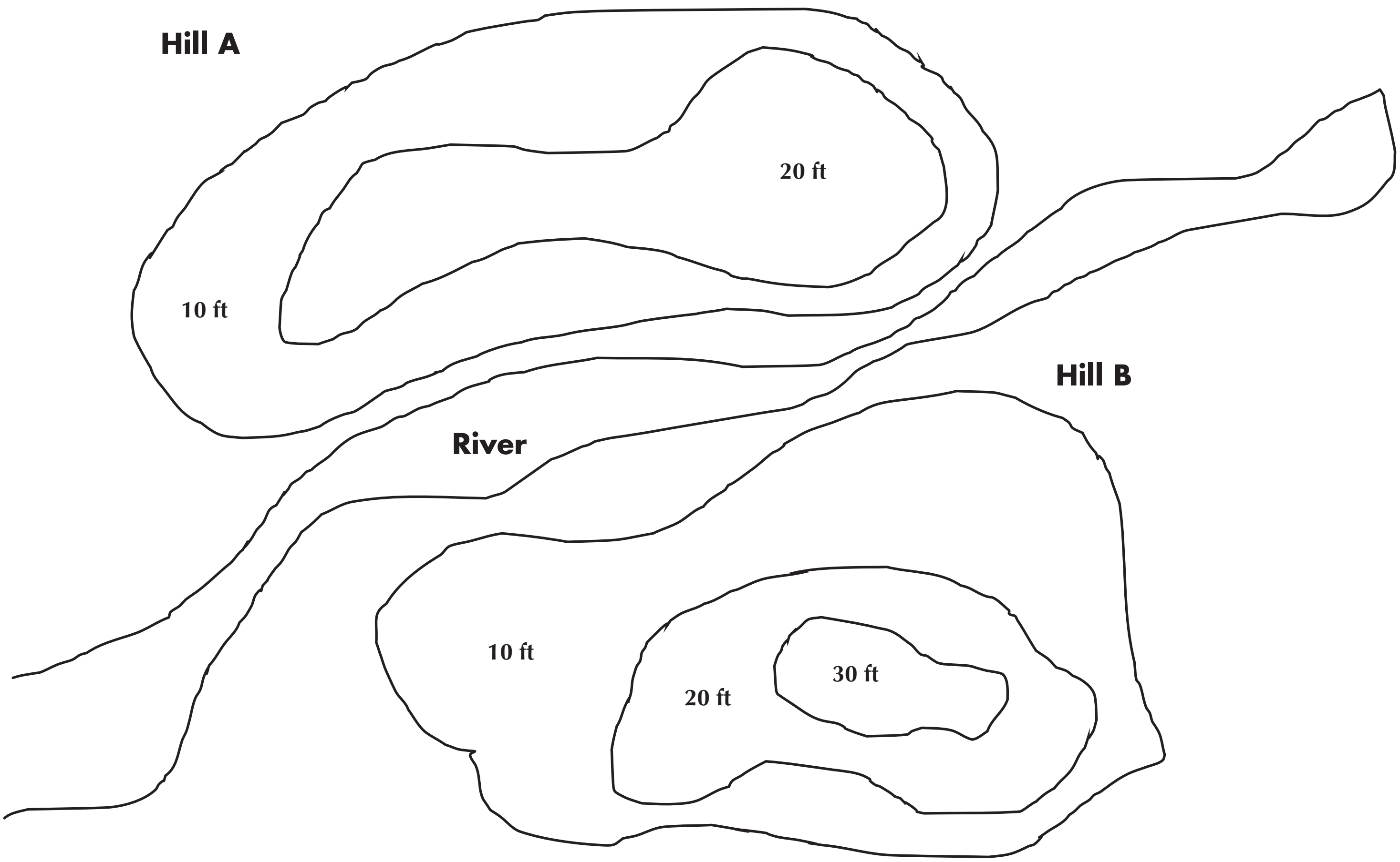
Simplify the activity by using the same basic materials and explanation, but break the class into two groups. Have each design a landscape. Then trade and have the other group build a bridge to cross the river. Discuss the issues faced when trying to create a bridge when the terrain is different on each side of the river. If possible, show students photos of real bridges crossing complex terrain, and ask the class to point out how engineers solved topographical problems.

Handout #1: Simple Topographic Mapping

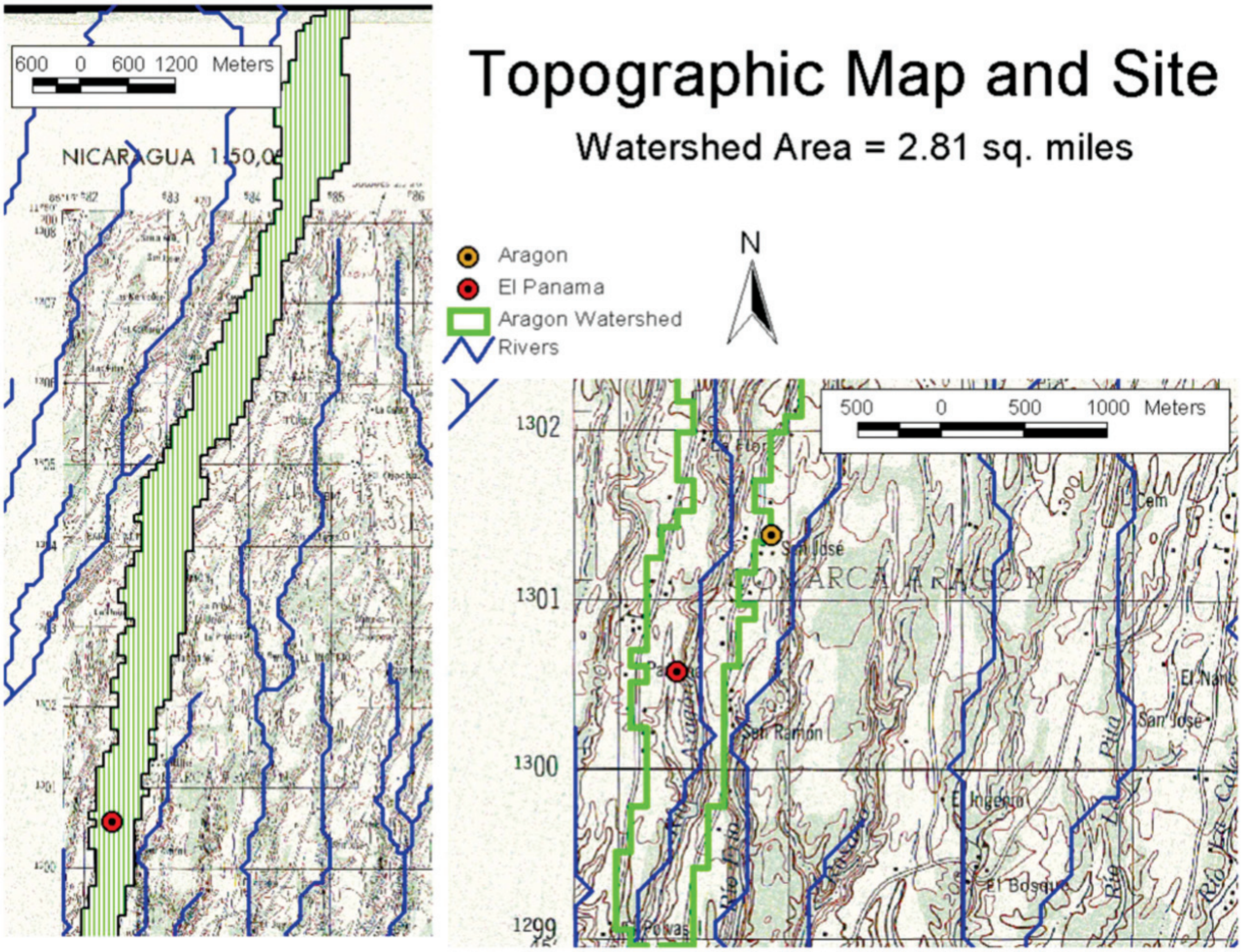
How tall is Hill A?

How tall is Hill B?

Where would you place a bridge to cross the river, and why?



Handout #2: Topographic Map



Implementation

Middle School

Images and information about various types of bridges will be presented to the students and then the students will select from a variety of simple materials to build a working model of a bridge.

Materials:

- Gumdrops and toothpicks
- Straws
- Tape
- Dental floss
- Scissors
- Paper clips
- Cups
- Pennies
- Fan

Online Resources:

http://www2.dot.state.oh.us/se/coveredbridges/truss_types.htm
http://www.tfhrc.gov/pubrds/winter97/p97wi32.htm
http://www.yesmag.ca/projects/bridge.html
http://www.yesmag.ca/projects/bridge.html
http://www.pbs.org/wgbh/buildingbig/bridge/basics.html
http://www.eweek.org/site/DiscoverE/popsicle.shtml
http://bridgecontest.usma.edu/tutorial.htm
http://42explore.com/bridge.htm

Procedure:

1. Break the class into groups, and ask students to find and share examples of each type of bridge using library/internet resources.
2. Watch DVD, if desired.
3. Still in groups, distribute gumdrops and toothpicks. Challenge each group to build a cube using gumdrops and toothpicks, and then reinforce their cubes with additional toothpicks. Students should find that adding diagonal supports will strengthen their cubes.
4. Challenge students to add reinforced cubes to one another to create the longest, strongest bridge they can build.
5. Test the bridges by suspending them between piles of books, and attaching a cup to the bottom of the bridge using a paper clip hook. Add pennies to the cup one by one. Which group built the longest strongest bridge? What was their secret?
6. Test the bridge for wind resistance using a fan from different directions. How is the bridge affected? Modify the designs to strengthen the bridge against the wind.
7. Put a load on the bridge, moving it from one end to the other. Measure the deflection of the bridge at the middle of the bridge when load is at 6 different points. Plot the results on a graph (position of load on X-axis, deflection on Y-axis). Repeat the process with two other loads. How does the deflection change with different positions? How does it change with different loads?

Extensions: Have students look up various truss bridge designs in books or on the internet, and create models of actual bridges using toothpicks and gumdrops, balsa wood, or other materials.

High School

Use the middle school project as a warm-up to constructing actual scale models of real bridges. In groups, have the students select a real bridge based on their own research, or select a bridge from this database at www.pbs.org/wgbh/buildingbig/wonder/index.html. Once they have selected a bridge and gathered the information needed regarding length, span, and structural details, use a variety of materials to build a scale model. Have the students share their models with other members of the class and/or the school.

Elementary School

Simplify the activity by completing only part one of the project described above. Next, have each child complete a number of triangles built of gumdrops and toothpicks, and then construct one bridge together. Ask students for their guesses (hypotheses) regarding how many pennies the bridge can bear. Test their hypotheses.

MATH

Assessment

Middle School

How wide must a bridge be? How strong? How high? To find out, students will conduct calculations based on information provided regarding water levels, maximum number and size of people, carts, cattle and cargo transported over the bridge.

Materials:

- Handout #3: Selection from the Final Design Report

Procedure:

Distribute handout to each student. Read it aloud together, and have students respond to the following questions:

- How high does the river rise during the rainy season?
- How high must the bridge be in order to provide a safe route during the rainy season?
- How long (span) must the bridge be?
- How wide must the bridge be?
- What is the "dead load" of the bridge?
- What is the greatest expected "live load" of the bridge?
- Eleven cows can cross the bridge at one time, end to end. How many people can safely cross the bridge with the cows?

Extensions: Select a local bridge, and look up its dimensions (length and width). Assuming that the average weight of an American car is 4,000 pounds, and the average length of an American car is 16 feet, what is the live load of the bridge? Remember to factor in multiple lanes.

High School

Expand the activity by including the extension and then break students into groups. Select a local or famous bridge to research. Have each group present a report showing and explaining the high, span, dead load and live load of the bridge they select.

Elementary School

Replace the middle school questions with the following:

If a bridge can hold 1,000 pounds, and each person weighs about 100 pounds, how many people can the bridge hold? What if each person weighs 80 pounds? 120 pounds? What if each person is carrying a load of 18 pounds? What if the people are in a cart weighing 200 pounds, drawn by a horse weighing 500 pounds?

Handout #3: Selection from the Final Design Report

A team of six conducted a preliminary survey trip in December of 2005 and gathered topographical data from a gorge in the community of El Panama, Nicaragua. During the rainy season, the water level in the gorge rises and makes it impassible. As a result, children and teachers cannot attend school, and the ill cannot access the Health Center located in the nearby city of Jinotepe. Our team decided that a bridge spanning the gorge would ensure better connections between the community and neighboring communities, facilitating both short and long distance accessibility. In the future, the bridge will create favorable conditions for the economic growth and social regeneration of the region. We discussed our plan with the members of the community, and it was enthusiastically embraced.

During the dry season, the community crosses the gorge shown below by foot using the boulders and stones on the riverbed as stepping stones. During the rainy season, the water frequently rises more than 9 feet from the riverbed. The banks leading to the riverbed are steep and made of igneous rock. Based on the highest water level, it was decided that a bridge of 22 meters is necessary to span the river during the rainy season.

Because the banks of the gorge are extremely steep, and the only nearby road is not paved, transporting materials to this site will be extremely difficult. This limits the size and weight of materials that can be used in the bridge design.

In designing a bridge, the dead and live loads on the bridge have to be considered. The dead load of the bridge is approximately 18,000 pounds. This is the dead weight of the deck and steel trusses. The live loads analyzed were based upon speaking to our engineering mentor and examining the community's needs. After speaking to Javier Garza, project mentor, he suggested that we consider a live load of 75 pounds per square foot. This load is equivalent to a bridge full of people, each person weighing 150 pounds and occupying an area of 2 square feet. This scenario is unlikely. The live loads expected on this bridge are cattle and people. The deck width of 4.92 feet will not permit carts or cars to pass. Initially, a load in which cows are lined up across the entire length of the bridge was considered as the worst-case scenario.

The average weight and length of each cow was taken to be 1,000 pounds and 6.6 feet, respectively. The bridge span and width are 72 feet and 4.92 feet. Taking these bridge dimensions and the characteristics of a cow, the load produced by cows lined up all along the bridge is approximately 31 pounds per square foot. This worst-case scenario is actually less than the 75-pound load considered initially. The probability of having 11 cows lined up one after another on the bridge is low. Therefore, the worst-case scenario considered is in fact that of people packed tightly on the bridge. No safety factor above the worst-case scenario was accounted for.

Design

Middle School

Given the information calculated in the assessment activity, and based on the idea of a bridge constructed of wood with a steel truss, students will determine how much wood would be needed for the bridge's wooden flooring.

Materials:

- Copies of handout for each student (same as the assessment activity)

Procedure:

Explain to students that EWB-USA participants are not sent to their destinations with pre-prepared plans for action. Instead, it's up to them to determine what the problem is, and develop a solution. Distribute handouts to each student. Pose the following questions:

- Assuming that wood is sold in 8- and 10 foot lengths and each plank is 18 inches wide, how many planks would be needed?
- Assuming $17/plank, how much will the wood cost to floor the bridge?
- Have students draw a picture showing cows lined up along the bridge. How many cows can cross the bridge at one time? Assuming one person (at 150 pounds) for every two cows, can the bridge handle the load?
- In the morning, groups of children must get to school. Assuming an average weight of 80 pounds per child, how many children can cross the bridge at once?
- The village sometimes uses oxen and carts to transport goods and supplies to and from the community of El Panama. An average ox weighs 775 kg and an empty cart weighs 200 kg. Ask students to develop their own questions about the live load capacity, and place the questions in a container. Have one student at a time come up to draw a question Challenge the class to develop answers based on the handout and their own calculations.

High School

Expand the activity by asking students to research various types of footbridges appropriate to a remote site. How much of each type of material would be needed to build a 22-meter long, 4.92-foot wide bridge? What would the material cost? What might be the costs of transporting the materials from Managua to El Panama?

Elementary School

Replace the middle school questions with the following: No motor vehicles can fit on the bridge, so a villager needing medical help might need to be transported over the bridge by cart. If an ox weighs 775 kg, an empty cart weighs 200 kg, and the person in the cart weighs 150 pounds, what is the total weight in pounds and kilograms?

Implementation

Middle School

Which polygon is strongest (triangle)? In this activity, students will experiment with straws and gumdrops to find out and construct a three-dimensional polygon and build a structural model based on findings.

Materials:

- 100 ordinary drinking straws, cut in half (alternatively, provide pointed toothpicks)
- Several large bags of gumdrops
- Rulers
- Flat toothpicks

Procedure:

1. Break students up into small groups, and have each group construct a cube using gumdrops and straw sections or toothpicks. Next, have students reinforce their cubes by adding diagonal supports on four sides of the cube. This is a representation of a portion of a truss bridge - the type of bridge that will be built by the EWB-USA students in Nicaragua.
2. How many gumdrops were used to build the reinforced cube? How many supports were used? If the bridge required eight similar truss structures, how many of each type of material would be needed? If desired, allow students to experiment to answer these questions.
3. Imagine that an 8-section long truss bridge made of toothpicks and gumdrops is a 1/10th scale model of a real bridge. How big would each toothpick and gumdrop be to create the full-sized bridge?
4. Provide students with flat toothpicks, and have them lay the toothpicks inside a cube to simulate the flooring of a bridge. How many toothpicks would be needed to floor an 8-cube bridge? An 18-cube bridge? If this were a 1/10th scale model, how wide would each toothpick be?

High School

Expand the activity by having students experiment with building more complex structures. If possible, have groups construct geodesic dome models and calculate materials required in a full-scale dome. If desired, consider building a model of a suspension bridge at www2.scholastic.com/browse/lessonplan.jsp?id=664.

Elementary School

Simplify the activity by using toothpicks or straws and gumdrops to construct a variety of two- and three-dimensional polygons. Measure perimeter, area, and, if appropriate, volume.

SOCIAL STUDIES/HISTORY

Assessment

Middle School

In this activity, students will discover basic Nicaraguan facts (geography, size, climate, population, historic facts), fill in an outline map of Nicaragua), and find the Rice University EWB-USA project location (El Panama) relative to other communities (Jinotepe, Aragon) that will be impacted by the addition of a bridge.

Materials:

- Maps:
  - Large world map
  - Nicaraguan map: www.lib.utexas.edu/maps/americas/nicaragua_pol_97.jpg
  - Nicaraguan outline map: www.nationalgeographic.com/xpeditions/atlas/index.html?Parent=nameri&Rootmap=nicara&Mode=b&SubMode=w
- Printout of CIA World Factbook article on Nicaragua: https://www.cia.gov/library/publications/the-world-factbook/geos/nu.html
- Computer with Internet and PowerPoint software (optional)
- Scissors

Procedure:

1. Present the class with a large-scale map of the world, and ask volunteers to locate Central America and Nicaragua. Ask students what they know about Central America and Nicaragua, and write down their answers on the board. Provide each student with a Nicaraguan map outline and political map. Have students fill in the Nicaraguan map outline, major cities/towns and geographic features such as rivers, lakes, etc.
2. Break students up into four groups. Ask students to imagine that they will be joining an EWB-USA team project in Nicaragua. Prior to leaving the USA, they will need to learn all they can about conditions in Nicaragua - ranging from weather to politics to culture.
3. Assign each group a topic to research and report on. Students may use books, the internet or encyclopedias to seek out information, but they must be sure their information is current. Topics to assign include climate and geography, culture, economics, and political conditions.
4. Have students work together to gather information about their topic. They may present their findings in the form of a PowerPoint Presentation, a poster, or a written report - but all groups should use the same format.
5. Have each team report on its findings to the group at large. Encourage the class to ask questions from the point of view of an EWB-USA member about to leave for Nicaragua (i.e., questions should be practical and appropriate).
6. Once all teams have made their reports, consolidate all reports into a single presentation, flip book or report.

High School

Have students complete the same activities as the middle school students, utilizing the CIA World Factbook website and BBC's Country Profile site news.bbc.co.uk/1/hi/world/americas/country_profiles/1225218.stm. Discuss societal issues (trade, economy, health, education, etc.). Who are the leaders of Nicaragua? Are there any particular precautions Americans should take when they visit Nicaragua?

Elementary School

Provide each child with both maps (Handouts #1 & 2). Discuss the location of Central America using the large classroom map, and have a volunteer point out Nicaragua. Have students use the various maps to fill in their outline map. Put a star where the EWB-USA team is working. Break into groups, and have each group research a topic related to Nicaragua (e.g., animal life, weather, family life, kids in Nicaragua).

Design

Middle School

To implement a civil engineering project in any community, everyone in the community must agree on where, when and how the project will be completed. This isn't always easy, since different people have different priorities, needs and expectations. In this lesson, students will learn what a stakeholder is, and will research the concerns of different stakeholders in their own community.

Materials:

- Access to the Internet
- Large poster board
- Markers

Procedure:

1. Explain to students that a stakeholder is any person or organization that has an interest in a project or plan. For example, imagine a family living in a rental apartment. They're thinking of buying a dog. Who might the stakeholders be in this decision-making process? In addition to the family, stakeholders would include the landlord (who might be worried about damage to his property), neighbors (who might be concerned about the noise), and possibly even the individual child who will be responsible for walking and feeding the dog.
2. Ask students who they think the stakeholders would be in a decision to create a year-round school year in the United States. Write answers on the board. Be sure to encourage students to think "outside the box," to include (for example) businesses like summer camps that cater to vacationing students; real estate agencies that rent summer homes to families; and so forth. Help students to see that "stakeholders" can be a large and diverse group.
3. Explain that, in Nicaragua, EWB-USA volunteers needed to work with many different stakeholders to determine whether, where, how and when a bridge would be constructed. Each stakeholder group had a different concern:
   - Only three local community members want to help build the bridge, but the EWB-USA team needs eight people to help.
   - Aramando, the El Panama community leader, wants to be sure the bridge is built quickly and inexpensively.
   - Farmers want to be sure that their cows can get over the bridge.
   - Doctors in Jinotepe want a safe way for people to be transported across the bridge (but the bridge won't be strong enough or big enough for cars or ambulances).
   - Students and teachers want the bridge to be ready for the start of the school year.

4. Ask students if they can imagine how these different groups might disagree with one another. Solicit at least four areas of potential disagreement (doctors might want to put off the project until they have enough money to build a vehicular bridge; community leaders might want the least expensive bridge; local labor may want EWB-USA students to do the work while EWB-USA student engineers want local commitment to the project, etc.)
5. Break students into groups, and assign each group a research project (library/internet).
   - When, how and why were local bridges built in your area?
   - Were there any disagreements relative to the location, cost, size, or materials used to build the bridge?

   If such information is not available, students may choose to research a famous bridge-building project such as the Brooklyn Bridge or the Chesapeake Bay Bridge.
6. Work as a class to identify the stakeholders involved in making bridge-related decisions in your community (or in the community you've chosen to research). Identify the roles those individuals play (e.g., homeowners, town officials, landowners, laborers, taxpayers, etc.).
7. Together, draw up a large stakeholder "map," showing each type of stakeholder and describing his or her particular point of view on bridges in your community (e.g., commuters want a quick way to get to the city, but homeowners don't like the traffic or pollution that a bridge might bring). Looking at your map, how might local stakeholders disagree and agree?

Extensions: Select a civil engineering topic of local interest, and have groups of students research and represent a point of view in a debate. Can they come to a decision? If possible, invite at least one representative stakeholder to visit your class (or visit that individual in their place of work).

High School
Complete the middle school project as well as the extension. Following the theoretical exercise, have students work in groups to develop one or more recommendations for managing real-life stakeholder differences relative to local bridge building projects. Recommendations should include any relevant statistics, existing programs, and cost estimates. For example, a plan for a bridge linking a suburb to a major city should include statistics, pros and cons relative to issues such as alternate locations, costs, traffic issues, pollution concerns, etc.

Elementary School
Complete the middle school project through Step Four. Select a topic of school-based interest in which there are at least four to six distinct stakeholders (for example - "students may no longer bring their own lunches to school" or "the school district will no longer provide bus service for students"). Help students to determine who the stakeholders are, and have groups work together to develop 3-5 arguments for their own point of view (for example - "kids who don't like the food in school lunches won't get enough to eat, and their school work will suffer"). Conduct a debate, with the goal of reaching a mutually satisfactory conclusion.

Implementation

Middle School

How does a new bridge affect its community? Review the DVD and describe what life is like in El Panama. Students will take a look at a bridge in your area and consider issues such as trade, transportation, education, etc. Predict how life will change after the El Panama bridge is implemented.

Materials:

- DVD player

Procedure:

1. View the video clips from the EWB-USA Nicaragua bridge project introduction and assessment segments. After watching the video, ask students to describe life in El Panama. How is it different from your own daily life? How does the river create community and barriers to community with Jinotepe?
2. Have students write a short story comparing and contrasting life today and ten years from now in El Panama.
   In the story, include:
   - Details of geography and climate (the rainy season, the rising river)
   - Details of daily life, based on the video
   - Realistic characters, based on the video
   - A realistic story based on your knowledge of stakeholders
3. Have students share their stories with one another. What do the stories have in common? How are they different? Does everyone in the class agree that life will be better or worse in the future? What are some of the issues that might arise with a new bridge in place?

Extension: Consider making a movie based on a selected student story.

High School

Complete the activity, and then research the real-life changes that have occurred as a result of bridge construction. Possibilities include bridges that played a role in military outcomes; bridges that changed the nature of a community; bridges that linked two disparate communities, etc.

Elementary School

Write a story as a class, focusing on the daily life of a young child and the ways in which his life will change as passage over the river becomes simpler. Possible scenarios include coping with medical emergencies before and after the bridge, building a friendship before and after the bridge, etc.

Notes