Bridge Building Contest

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Educational Goals Design, sketch and fabricate a structure according to certain parameters. Understand structural forces. Learn rudimentary cost estimating and how to build within cost estimates.

Description Created by the Los Angeles Metro Area affiliate, this activity was designed as a competition among all the schools participating in the ACE program. It was held on a Saturday in a central location. Individual ACE teams, however, can readily adapt the activity as an exercise or, if so desired, as a small competition among several small groups of students. Note: Individual ACE teams may want to simplify the activity somewhat by deciding to use just one building material, either spaghetti or popsicle sticks.

Students first design and sketch a bridge to meet predetermined requirements. Next they estimate the cost of their design, and finally construct a bridge according to their design and using a variety of materials. Bridges are tested for their load-bearing capacities. In addition, their cost-efficiencies (as measured by the ratio of load to material cost) are also calculated.

BRIDGES

Time 2-3 hours

Materials

Each team will be provided with the following materials, in unlimited quantity except for the glue guns:

- Four hot-melt glue guns
- Hot-melt glue sticks
- Spaghetti
- Popsicle sticks
- Paper (for drawing the bridge design and making calculations. Paper can also be used as a structural element of the bridge, if students desire.)
- String
- On request, penne, ziti, rigatoni, and rotelle
- A copy of the Design Requirements and Construction Rules set forth below
- One copy of the *Bridge Building Competition Cost Estimate Worksheet* that follows

STRUCTURAL ACTIVITIES
BRIDGE BUILDING CONTEST

DEVELOPED BY:
THE ACE MENTOR PROGRAM OF LOS ANGELES - ORANGE COUNTY

The judges will have available for any team to temporarily use:

- An abutment template for laying out the dimensions of their bridge (This template is simply a line drawing of the two abutments on paper so the teams can visually understand the distance they must span.)
- A model test vehicle that must pass over the roadbed of the bridge
- Design paper, pencils and rulers
- Scissors and diagonal cutters

Judges will also need the following items for purposes of testing the completed bridges:

- Two or three toy cars or trucks (all the same). Students use these to test the physical clearance along the roadbed.
- A set of scales with which to weigh student-made bridges and a bucket with weights used to test the load-bearing capacity of bridges.
- A 3" x 3" flat load test block (see picture at the end of this activity description). The test block was constructed with a 3" x 3" square steel washer used in California on Type V structure anchor bolts. It is about ¼" thick, with a ⅝" hole in the center. Through that a machine screw eye bolt, about ¼" in diameter by 4" long, is run. The screw, end up, is slipped into the student's bridge, through the 3" x

3" washer, and a fender washer and nut are placed on it. This leaves the eye-end hanging down below the bridge. A carabineer is placed on the eye, which is used to attach a metal bucket into which lead weights are loaded one at a time until failure of the bridge.

- One bucket, to hang from the test bloc
- Weights to fit in the bucket, for purposes of testing the load-bearing capacity of bridges
- Two 3'- or 4'-long 2" x 4"s to serve as abutments on which to lay bridges for testing purposes and two clamps with which to attach the 2"x 4"s to a table.

Concept

Teams will consist of ACE students and their mentors. Only the students may work on the project; however, mentors may advise and coach. Teams will design and build a bridge structure using a choice of several materials. Teams will also produce a cost estimate for their bridges. The designs, estimates and bridges will be judged for several qualities, and then the bridges will be tested for capacity with static loadings.

Depending on which of the available materials students choose to construct their bridge, the distance the bridge must span for testing will vary. Simply put, bridges that forego the use of popsicle sticks for structural support will be tested at a span of 20". Bridges that utilize popsicle sticks in a structural capacity will be tested at 30".

Schedule

A. Once the competition begins, there will be ten minutes dedicated to questions and answers regarding the problem. After that, there will be two hours for the design and construction of the bridges.

B. Each team must develop a design for their bridge and produce a drawing(s) and cost estimate during the two-hour period.

C. Each team makes its own decision as to when to start the physical construction of its bridge, and must complete construction within the two-hour period. The judges should urge the teams to begin construction as soon as their basic design approach is determined so that there is adequate time to complete the work.

D. At the end of the two-hour period, construction must stop, and judging and testing will begin.

Design Requirements

A. Bridges utilizing popsicle sticks in their structure must span exactly 30 inches between two fixed abutments. Bridges that do not use popsicle sticks in their structures must span exactly 20 inches between abutments.

B. Bridges may not be longer than 2 inches more than the distance between abutments (maximum 1" bearing on each abutment). A bridge using popsicle sticks may not exceed 32" and a bridge with out popsicle sticks may not exceed 22" total length.

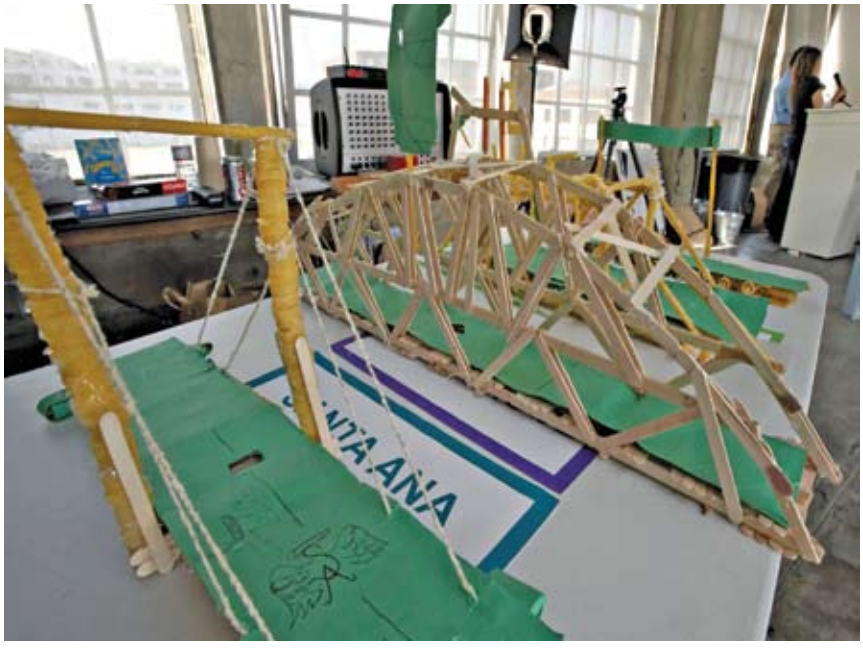
C. Bridges may not be wider (in plan view) than 6" at any point.

D. No component of the bridge may extend more than 1" below the top surface of the abutments (in an un-loaded condition).

E. There is no limit as to the total height of the bridge.

F. Bridges must have a substantially flat and level roadbed, at least 3" wide, adequately high and clear along its entire length so as to allow the free passage of the test vehicle.

G. The roadbed, extending the full length of the bridge, must be "paved" with any choice of materials that allows the test vehicle to roll over it reasonably smoothly. Gaps along the center, where



the wheels would not travel, are acceptable. A small gap or opening must be placed at the dead center, to allow the loading of the test block, as described below. The roadbed must not be elevated excessively above the surface of the abutments. A driving surface within an inch vertically of the top surface of the abutments will meet this rule. Ramps of reasonable slope are allowable, provided they do not begin more than 1" above the abutment and the bridge otherwise meets the dimensional rules stated above.

H. Bridges must be designed so that no lateral loads are placed onto the abutments.

I. Bridges must be designed to allow the placement of a 3" x 3" flat load test block onto the roadbed at the center of both axis (in plan) and provide an opening or gap in the roadbed and structure for the insertion of a ¼" bolt into the load test block from below.

J. In order to ensure the retention of the load test block on the road bed during testing, the judges recommend the use of popsicle sticks in the center area of the roadbed. Bridges that want to compete at the 20" abutment distance will be allowed the use of popsicle sticks for roadbed paving of up to 50% of the total length of their bridge (11" max).

K. Bridges may utilize only those materials that are provided for the competition.

Construction Rules

A. Only the supplied materials may be used.

B. The supplied materials (paper, pasta, string, popsicle sticks) may be cut, bent, folded or otherwise manipulated in any way the team chooses.

C. Hot-melt glue sticks may only be used for adhesion, and may not be used in their original (stick) state.

D. There is no limit on the number or configuration of materials used to construct the bridge, or to make up individual structural elements, as long as teams use only those materials that are provided for the competition. There is no limit on the amount of hot-melt glue used. Teams should be aware, however, that using excess materials will add weight to their structure and may possibly penalize their team in scoring.

Flat Load Test Block

Initial Judging

Using the *Bridge Building Competition Judging Sheet* that follows, judges will evaluate bridges for the following characteristics:

A. Design
   a. Clarity of the drawing(s) – is the intent of the design obvious?
   b. Draftsmanship – is the drawing work neat and professional?
   c. Compliance – do the drawings reflect a bridge that complies with the design rules?

B. Cost estimate
   a. Is the cost estimate complete?
   b. Is the cost estimate accurate when compared with the design and actual bridge?

C. Construction
   a. Does the bridge utilize only the materials supplied for the competition?
   b. Does the bridge comply with the dimensional requirements?
   c. Does the bridge match the design depicted on the team's drawing(s)?
   d. How neat and craftsman-like is the construction?
   e. How aesthetically pleasing is the bridge?
   f. How creative or distinctive is the bridge?

Testing Station

Once the initial judging is complete, the structures will be tested for load-carrying capacity.

Static Testing

Using the *Bridge Building Contest Load-Testing Score Sheet* that follows, judges will calculate the structural efficiency ratio and cost-efficiency ratio for each bridge.

A. Each bridge will be weighed prior to testing.

B. Each bridge will then be tested to determine its load-carrying capacity, using the following procedure:
   a. The bridge will be placed in position at the testing station.
   b. The load test block will be mounted at the center of the bridge.
   c. The load test bucket will be connected to the test block.
   d. The static load will be placed in the test bucket, incrementally increasing the load until structural failure of the bridge, as defined below.

Structural Failure

Structural failure is defined as the first occurrence of either of the following:

A. Permanent deflection of any portion of the bridge in any direction by 2 inches or more.

B. Failure of the bridge to retain the load test block on the road bed surface.

Awards

Ideally, every team goes home a winner. Consequently, many different awards can be created such as follows:

Most Structurally Efficient Bridge *(the bridge that achieves the highest ratio of load supported divided by the weight of the bridge itself)*	**Best Cost Estimate** *(the cost estimate that is most professional and accurate)*
Most Cost-Efficient Bridge *(the bridge that achieves the highest ratio of load supported divided by the cost of the bridge materials)*	**Most Aesthetically Pleasing Bridge** *(the bridge that presents the most aesthetically attractive appearance, regardless of function)*
Strongest Bridge *(the bridge that supports the most load, regardless of its own weight)*	**Most Innovative Bridge** *(the bridge that exhibits the most unique, creative or unconventional design)*
Lowest Cost Bridge *(the bridge that achieves the lowest overall cost of materials)*	**Best Use of Varied Materials** *(the bridge that best uses a variety of materials in its construction, vs. reliance on any one predominant material type)*
Best Construction Workmanship *(the bridge exhibiting the neatest, most precise construction)*	**Best Italian Meal** *(the bridge reflecting the best use of pasta in its construction)*
Best Design Drawings *(the drawings exhibiting the neatest, most draftsman-like work, as well as accurately depicting the actual bridge built)*	**Judges' Award** *(discretionary)*

Bridge-Building Competition
Cost Estimate Worksheet

Team: _____

Cost Estimate:

Material	UM	Cost / UM	Total Qty	Cost Extension
Popsicle Stick	EA	$10		
String	LF	$20		
Paper	Sheet	$40		
Pasta	EA	$1		
			Total Direct Cost:	

Quantity Take-off:

Popsicle Sticks

String

Paper

Pasta

Bridge-Building Competition
Load-Testing Score Sheet

Team:		Weight supported:	
Weight of bridge:		Cost of bridge:	
Struct. Efficiency ratio:		Cost Efficiency ratio:	
Team:		Weight supported:	
Weight of bridge:		Cost of bridge:	
Struct. Efficiency ratio:		Cost Efficiency ratio:	
Team:		Weight supported:	
Weight of bridge:		Cost of bridge:	
Struct. Efficiency ratio:		Cost Efficiency ratio:	
Team:		Weight supported:	
Weight of bridge:		Cost of bridge:	
Struct. Efficiency ratio:		Cost Efficiency ratio:	
Team:		Weight supported:	
Weight of bridge:		Cost of bridge:	
Struct. Efficiency ratio:		Cost Efficiency ratio:	
Team:		Weight supported:	
Weight of bridge:		Cost of bridge:	
Struct. Efficiency ratio:		Cost Efficiency ratio:	
Team:		Weight supported:	
Weight of bridge:		Cost of bridge:	
Struct. Efficiency ratio:		Cost Efficiency ratio:	
Team:		Weight supported:	
Weight of bridge:		Cost of bridge:	
Struct. Efficiency ratio:		Cost Efficiency ratio:	
Team:		Weight supported:	
Weight of bridge:		Cost of bridge:	
Struct. Efficiency ratio:		Cost Efficiency ratio:	
Team:		Weight supported:	
Weight of bridge:		Cost of bridge:	
Struct. Efficiency ratio:		Cost Efficiency ratio:	

All-Schools Bridge Building Competition
Judging Sheet

Team: _____

Abutment distance designed for: ____ 20" ____30"

I) Design

A) Draftsmanship - is the design work neat and professional?
B) Compliance - does the design reflect a bridge that complies with the rules?

II) Cost Estimate

A) Is the team's cost estimate accurate compared with the actual bridge?
B) What is the Judge's estimate of the bridge cost? | |

III) Construction

A) Materials - did the team use only the allowed materials?
B) Dimemsions - does the bridge comply with dimensional requirements?
C) Design Match - does the bridge reflect the design?
D) Craftsmanship - how neat and professional is the construction?
E) Aesthetics - how aesthetically pleasing is the bridge?
F) Creativity - how unique or creative is the bridge?

IV) Testing

A) Weight - how much does the bridge weigh? | |
B) Strength - how much load did the bridge support without failure? | |

V) Calculations

A) Cost Efficiency - Load Supported (ounces) divided by Cost (dollars) | |
B) Structural Efficiency - Load Supported (ounces) divided by Weight (ounces) | |

VI) Tentative Award

A) Most Structurally Efficient Bridge	
B) Most Cost-Efficient Bridge	
C) Strongest Bridge	
D) Lowest Cost Bridge	
E) Best Construction Workmanship	
F) Best Design Drawings	
G) Best Cost Estimate	
H) Most Aesthetically Pleasing Bridge	
I) Most Innovative Bridge	
J) Best Use of Varied Materials	
K) Best Italian Meal	
K) Judges Discretionary Award	

VII) Comments