Bridge building competition

Updated 8 Feb 2009

Materials:

- Spaghetti
- Flat pasta, e.g. fettuccini or tagliatelle (optional)
- String
- Scissors for the tape & string – 1 pair is sufficient, but it would be nice to have more pairs
- Ruler
- Sellotape or comparable clear adhesive tape (at least 3m per group)
- Photos of various bridges (optional)
- Triple beam balance capable of weighing at least 1 kg. If a balance is not available, see note at end for an alternative option that uses a graduated cylinder.
- Flat block of rigid material (plastic, wood, metal, etc.) A piece of roughly 8 cm x 8 cm square works well, though the size is not critical.
- Two desks or chairs
- Plastic bottle, 1-2 litres
- Paper clip (could use wire or string to substitute)
- Water
- Funnel (optional)

Suitable for: 9-60 students

Time required: If there are three groups and if Section II is skipped, then the activity will take at about 2.5 hours. Each additional group will add 5-10 minutes to the weighing. If needed, the construction could be begun on one day and the weighing and competition done on a later day.

Topics discussed: use of triple beam balance, teamwork, planning, tradeoffs, strain of materials.

I. Introduction

Announce to the students that we will be having a bridge-building competition, and describe all of the following rules:

The bridges will be ranked according to an "efficiency" score:

$$\text{efficiency score} = \frac{\text{weight of maximum load supported}}{\text{weight of bridge itself}}$$

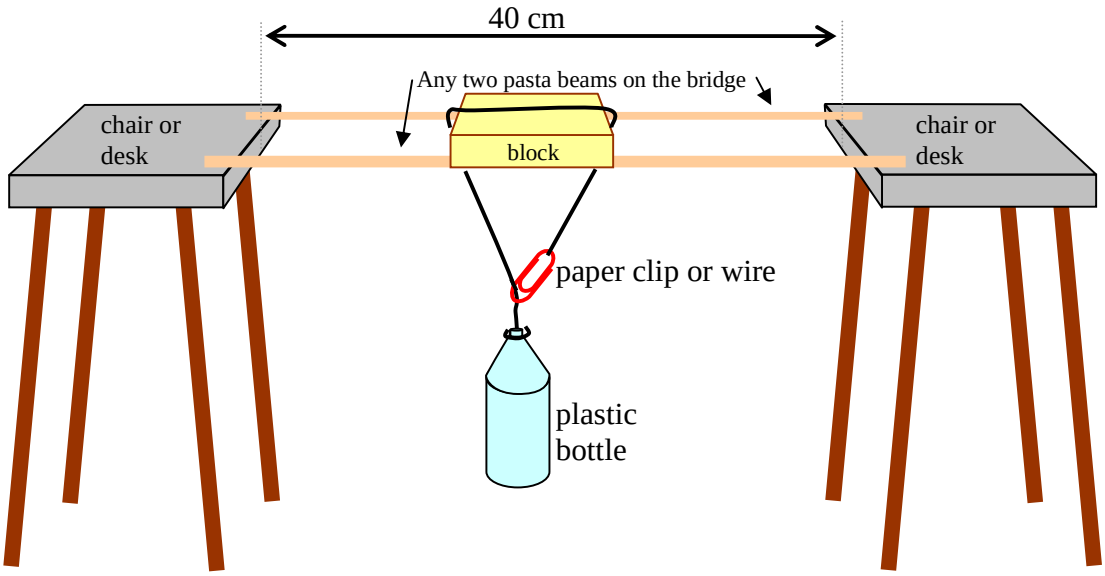
This formula was designed to model the tradeoffs that occur in a real construction project, e.g. some materials are stronger but more expensive.

The students will work in groups. Each group should choose a name. It makes sense to choose the group size such that the total number of teams is at least three but no more

than eight. Each bridge can use only pasta and tape. (Some versions of this event use glue rather than tape, but with tape you do not need to wait a day between construction and testing). Depending on how much pasta and tape you have available, it may make sense to impose an upper limit on the quantities of each material used per team. We found that a limit of 3m of tape per team worked well.

The bridges will have to span a specified distance between two desks. We found that a good distance for the gap was 40 cm.

To measure the maximum weight the bridge can carry (the "load"), block is placed on the bridge and the string and bottle attached as follows:



The reason for hanging the weight from the block (rather than attaching the string directly to the pasta) is to allow the weight to be spread across separated beams without causing beams to be pulled together horizontally.

Specify that the pasta cannot be taped to the desks or chairs for the competition.

II. Principles

This section can be skipped in order to save time if you are trying to fit the entire activity into a single 2.5-hour session.

Each team is given 10 minutes to experiment with the building materials and to look at photos of various real bridges. Each team must write down at least one principle – preferably more - which they hypothesize would make for a high-efficiency bridge. (e.g. use the fettuccini with the long direction vertical rather than horizontal, like an I-beam). Each group must also sketch a design of a possible bridge that implements this principle.

Each group then makes a one minute presentation to the rest of the class at the chalkboard, writing down the principle(s) they articulated in the previous step, and drawing their tentative design.

III. Design and construction.

Each group now reassesses their bridge design in light of the ideas presented in Section II. The groups now have a large block of time to construct their bridge for the competition. If you are putting an upper limit on the amount of pasta and/or tape used, we found it worked best to hand these out a bit at a time, using a table to keep track of how much material each group had used so far:

Team name	Spaghetti used, max 40	Tagliatelle used, max 20	Tape used (m), max 3
Lions	30	15	1.5
Rhinos	25	15	2
Elephants	35	20	1.5

This method conserves materials because you don't automatically give out the maximum amount of pasta and tape.

At regular intervals, announce how much time is remaining for construction.

IV. Testing

As the time approaches for the end of the construction period, make the following table on the chalkboard:

Team name	Weight of bridge (g)	Maximum load (g)	Efficiency score
Lions			
Rhinos			
Elephants			

At the announced time, all of the bridges are all "impounded" so the students cannot make further modifications while other groups' bridges are being tested. Have the first group put their bridge on the balance, find the weight, and record the value in the table on the chalkboard.

Now, test the maximum load which this bridge can support:

1. Make sure the two desks or chairs are separated by the specified distance (40 cm)
2. Mount the bridge between the two desks or chairs.
3. Attach the block, string, and water bottle as in the figure above.
4. Slowly pour water into the bottle to increase the load. You can use a funnel for this purpose if one is available.
5. A student should be ready to catch the bottle as soon as the bridge collapses. It is important to not let the water spill when the bridge collapses, because we will need to measure the weight of the load. (It is not a problem though to spill water as you are adding it to the bottle while increasing the load.)
6. If the bridge buckles and falls but does not break, the students then have two chances to reposition the bridge, block, and string and try to increase the load.

The testing ends if the bridge buckles and falls a third time, even if none of the pasta has broken.

7. The block, string, and bottle of water are placed on the balance. A student should measure the weight of this maximum load and record the value in the table on the chalkboard.
8. The efficiency score of the bridge is calculated.

Now Group 2's bridge is weighed, then the block and bottle are attached to the bridge and its load is tested. Then Group 3's bridge is weighed and tested, etc.

V. Recap

Each team meets again to identify at least one principle which they took away from the results of the competition. After 2-5 minutes of discussion in groups, each team then goes to the board to state and record the principle(s) they identified.

You may wish to award a prize for the team or teams with the highest efficiency score(s).

VI. Repeat

If there is interest among the students, you can run the competition a second time. This way, students can learn from their first attempts and try to improve their designs in the second round.

Alternative if balance is unavailable

If you do not have a suitable balance for weighing the bridges and the loads, one way to proceed is to use the following alternative efficiency score:

$$\text{efficiency score} = \frac{\text{maximum volume of water supported}}{\text{cost of materials used}}$$

The "cost" for each material is a fictitious value which you can invent: perhaps try 1000 Kw per piece of spaghetti, 3000 Kw per piece of tagliatelle, and 5000 Kw for each 50 cm length of tape.

The volume of water used in the load can be measured with a suitably large graduated cylinder.

References:

Science Olympiad bridge competition rules:
http://soinc.org/elevated_bridge_b

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http://soinc.org/sites/default/files/uploaded_files/trial_events/beambuild.pdf