

Build, Test, Improve: Paper Bridge

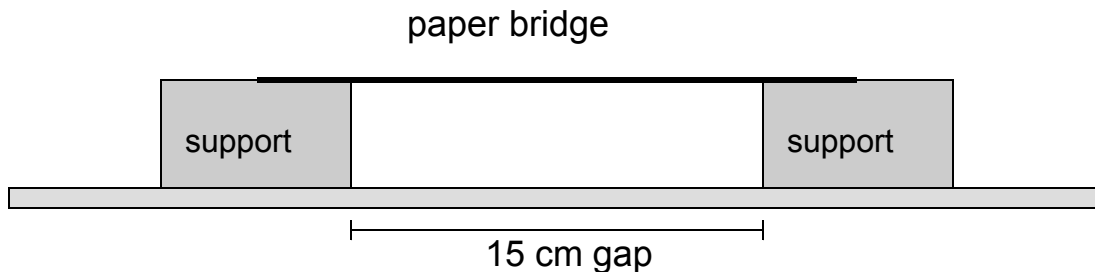
Plan a fair test, use evidence, and improve an engineering design

Name: _____ Date: _____

Part 1 - Plan a Fair Paper-Bridge Test

Challenge: Build a paper bridge that spans two supports 15 cm apart and holds as many identical load units as possible before it fails. A failure happens when the bridge touches the table, tears, slides off a support, or drops a load.

Materials: 6 identical sheets of paper - one fresh sheet for each trial - 2 equal-height supports, identical load units, ruler, and pencil. Follow your teacher's safety directions. Do not throw loads or stack loads above your teacher's limit.



1. Identify your investigation. Start with a flat-sheet bridge. Then change *one* design feature for your improved bridge. This is an experimental investigation within an engineering design challenge.

Tested variable: What one feature will you change?	My prediction: Which design will hold more? Why?

2. Keep conditions controlled. Circle or add conditions you will keep the same: paper type, paper size, 15 cm gap, support height, load type, load placement, adding one load at a time, and

_____.

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Part 2 - Write Your Fair-Test Procedure

3. Write your fair-test steps. Include using a new, undamaged sheet for each trial, how you will place loads, and how you will decide that a bridge failed.

Check before testing: Your steps should explain how you will keep the tested variable as the only planned difference between the flat-sheet bridge and the improved bridge.

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Part 3 - Carry Out the Investigation

4. Test. Build a fresh bridge from a new, undamaged sheet for every trial. Do not reuse a sheet that has bent, creased, torn, or carried loads in an earlier trial. Test each design three times. Use the same failure rule each time. Record the number of load units held immediately before failure. If a trial has a problem not caused by the design, mark it with * and repeat it using another fresh sheet.

Safety cap: Your teacher will name a maximum number of loads. If a bridge reaches that maximum without failing, stop. In the trial cell, use the compact notation **cap; ≥ 20** , changing 20 to your teacher's cap. This is not a failure result.

Design	Trial 1	Trial 2	Trial 3	Total and mean only if all trials failed
Baseline: flat sheet				
Improved: _____				

Mean rule: If all three trials failed, total the three results and divide by 3. If any trial reached the cap, write “no exact mean - cap reached.” Do not treat the cap as a failure result.

Reset check: Before every trial, I have a fresh, undamaged sheet; the supports are 15 cm apart; and I will use the same loads, placement, and failure rule.

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Part 4 - Compare Evidence and Improve

5. Compare evidence. Which design has stronger evidence of holding more? Use a mean only when it is exact. If a cap was reached, compare using “at least” language. If both designs reached the cap and the evidence cannot rank them, say so.

6. Explain your design decision. Use numbers or capped-trial evidence from your table. Did the evidence support your prediction? What will you keep, change, or test next?

7. Engineering sketch: Draw your improved bridge from the side. Show two supports and label the one changed feature.

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Teaching Notes - Setup and Investigation

Materials to supply: Print and supply all student pages, keeping teacher-key pages separate. Per team: at least 6 identical sheets of copy paper, one for each planned trial, plus replacement sheets for invalid trials; two equal-height supports such as blocks or same-size books; ruler; pencil; and at least 20 identical load units such as washers, linking cubes, or plastic counters. Also provide a flat tray or desk surface. Do not use liquids, sharp objects, or heavy objects.

Exact setup and safety: Place supports on a flat surface with their inside edges exactly 15 cm apart. Mark the support positions with masking tape so the gap remains constant. Tell students to place loads at the midpoint of the bridge, one at a time, and to stop at the first stated failure. Set a teacher maximum appropriate to the materials, such as 20 load units. Students must keep hands clear while a partner adds loads, must not throw loads, and must return loads to the container after each trial.

Trial-reset protocol: Every trial requires a fresh, undamaged sheet. A paper bridge that has held loads, been folded, creased, torn, slid, or otherwise changed during a trial may not be used again. Students use three fresh sheets for the flat-sheet baseline and three fresh sheets for the improved design. If a trial is invalid because a support moved, a load was bumped, or another problem was unrelated to the design, students mark the result with an asterisk, restore the 15 cm setup, and repeat with an additional fresh sheet. Supply replacements as needed until each design has three usable trials.

Capped-trial protocol: A trial that reaches the teacher maximum without failure is usable but is capped, not failed. Students record the compact notation “cap; ≥ 20 ” or substitute the stated cap. They do not include that result in a total or ordinary mean. If a bridge reaches the cap of 20 without failing, students may state that it held at least 20 loads. Do not ask students to claim an exact average or exact difference from a capped trial.

Teaching script: Read: “Today you are engineers and investigators. Your goal is not to get a particular number. Your goal is to make a fair comparison. Begin with a flat-sheet bridge. Change only one design feature for the improved bridge. Keep the gap, paper type and size, supports, load type, load position, and loading method the same. Every trial gets a fresh sheet, because a used or damaged sheet would not be a fair comparison. Record what actually happens. If your bridge reaches our safety cap without failing, that tells us it held at least that many loads. It does not tell us the exact number it could hold. A result that surprises you is still useful evidence.” Ask: “What is one variable you can change? What must stay the same?”

Observation method: Circulate with this checklist: gap measured 15 cm; baseline is flat; one named feature changes; a fresh undamaged sheet is used for each trial; loads are identical and centered; one load is added at a time; three usable trials per design are recorded; capped trials are marked clearly; and the student uses table values appropriately in the conclusion. Do not supply or correct students' results. If a bridge slips because a support moved, have students mark the trial and repeat it with a fresh sheet after restoring the setup.

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Answer Key and Scoring Notes

- 1. Tested variable and prediction:** Accept a single, testable design feature, such as number of folds, fold direction, a rolled-paper beam, accordion folds, or paper orientation. Sample: “I will change the paper from flat to two lengthwise folds.” The prediction must name a design and give a reason. Reasoning may be tentative.
 - 2. Controlled conditions:** Accept at least four appropriate controls, including the 15 cm gap and identical loads. Sample additions: same midpoint placement, same paper sheet size and type, same support height, fresh undamaged paper for every trial, and one load added at a time.
 - 3. Fair-test procedure:** Full credit includes building the baseline with a fresh sheet, placing one centered load at a time, counting until the stated failure or safety cap, recording the result, discarding that trial's sheet from further testing, repeating three times with fresh sheets, and then repeating with only the named feature changed.
 - 4. Trial table:** There is no fixed numeric answer. Each row needs three observed usable results from separate fresh sheets. For failures, students record the number held immediately before failure. For a capped trial, students record “cap; $\geq$ [cap].” Asterisked invalid trials should be repeated with a fresh sheet and not included in a calculation. Students calculate a total and mean only when all three trials in that design failed below the cap.
 - 5. Comparison:** When both designs have three uncapped failure trials, accept a correct comparison of calculated means. A student does not need to subtract the means because the student prompt does not request a difference. If means tie, “neither was greater” is correct. When one or more trials are capped, accept only claims supported by the evidence. Sample ranked comparison: “The baseline failed at 8, 9, and 10 loads, while the improved design reached at least 20 loads in two trials. The improved design has stronger evidence of holding more, although its exact mean is unknown because it reached the cap.” Sample insufficient-evidence comparison: “Both designs reached at least 20 loads. Because both exact maximums are unknown, the evidence does not rank the designs.” Do not require or accept an ordinary mean that treats the cap as a failure result.
 - 6. Evidence-based decision:** Full credit: claim names the better-supported design, states that results were tied or mixed, or explains that capped evidence limits an exact comparison; evidence cites table values or “at least” values from both designs when ranking them; reasoning connects the evidence to the next design decision. Do not require the prediction to be supported.
 - 7. Sketch:** The sketch must show a bridge spanning two supports and label the one changed feature.
- Suggested 12-point rubric:** 1-2 points for a testable variable and prediction; 3-4 for controls and procedure; 5-6 for complete fair-test data and appropriate calculations or cap notation; 7-9 for evidence-based comparison; 10-11 for an evidence-based next step; 12 for a labeled sketch that accurately matches the improved design. Award reasoning points for sound use of actual evidence, not for a particular bridge shape or load total.