

STEM Design-Test-Improve Studio: Six Build Investigations

A bridge design brief, a test data sheet and 6 activities, each with a worked answer.

DESIGN CYCLE

Plan

Sketch it

Build

Make it

Test

Repeat fair trials

Improve

Change one thing

TEST LOG

Version	Trial 1	Trial 2	Trial 3
V1			
V2			

HOW TO USE

1. Read the design brief and plan your build.
2. Test fairly and record every trial.
3. Use the data to decide what to improve.
4. Retest and explain what changed.

6 activities • 3 answer pages • From the 24-activity collection

12 US Letter pages • Print at 100% / Actual Size

Original Bobotemp educational printable • Fictional names, places and prices

DESIGN BRIEF

The Index-Card Bridge

The class library needs a bridge between two book stacks. Your team will build a one-card bridge across a 15 cm gap, find out how many pennies it holds, and use your test data to make it stronger.

Materials (per team)

- 9 index cards plus spares, 5 × 8 in (about 20 cm long), so each design and each retest can use a fresh card
- Masking tape and a centimeter ruler
- 2 stacks of books of equal height, about 3 cm tall
- About 100 pennies in a cup (all one kind of coin)
- Pencil and this workbook

CONSTRAINTS

Use 1 index card per bridge. The gap between the book stacks is 15 cm. Tape each end of the card to its stack with 2 cm of tape and no other tape. You may fold or bend the card, but you may not cut it or add other materials.

TEST RULE

Add pennies one at a time to the middle of the deck. Stop when the deck touches the table. Count every penny on the deck, including the one that made it touch. If the card slips off a stack first, stop, count the pennies and write a note. Use this same rule for every trial.

Success criteria

- ☐ The deck spans the 15 cm gap and rests on both stacks before testing.
- ☐ We tested each design 3 times with the same test rule.
- ☐ We recorded every trial in pennies and found each total.
- ☐ We chose one change for a redesign and can explain it with our data. (Sketch on spare paper with the folds running from stack to stack; copy the test table to retest your redesign 3 times. The six activities use fictional test data.)

TEST DATA SHEET

Bridge Test Data

KEEP IT FAIR

Keep these the same for every trial: the 15 cm gap, the card size, 2 cm of tape at each end, the place where pennies go (the middle of the deck) and the test rule. Change only the shape of the card.

PENNIES HELD (COUNT WHEN THE DECK TOUCHES THE TABLE)

Design	Trial 1	Trial 2	Trial 3	Total	Mean (total ÷ 3)
A: flat card					
B: folded card					

How to measure

1. Before each trial, measure the gap again with the ruler: it should still be 15 cm.
2. Place pennies one at a time in the middle of the deck. Do not drop them.
3. One partner watches the deck from the side, at table level, and says "stop" when it touches the table.
4. Count every penny on the deck, then put them back in the cup.
5. Run 3 trials for each design. If a card creases or tears, use a fresh card and write a note.

Notes about any trial that went wrong:

Which design held more pennies? Did it win in every trial? Use your numbers.

Name _____ Date _____

LEVEL 1



Read the test table. Use the numbers as your evidence.

Two index-card bridges span a 15 cm gap between two book stacks. Testers added pennies one at a time until each deck touched the table, and counted every penny on the deck, including the last one. Find the total number of pennies the folded bridge held across three trials. Then decide which design was stronger.

TEST SETUP

Build: 1 index card, 15 cm gap, 2 cm of tape at each end

Stop rule: stop when the deck touches the table; count the penny that made it touch

1. Add the three folded-bridge trials.

[illegible]

3. Explain why three trials are better evidence than one.

A large rectangular area filled with a light gray background and a white grid pattern, resembling graph paper. The grid consists of approximately 20 columns and 10 rows.

TRY IT • A third design held 15, 17, and 16 pennies. What is its total, and where does it rank?

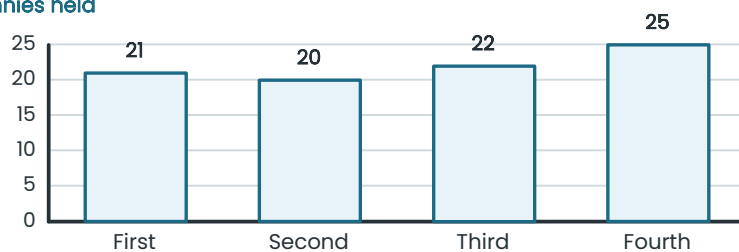
Name _____ Date _____

LEVEL 2 ●●○

Use all four trials to find the mean (average) result.

The folded index-card bridge was tested four times across the same 15 cm gap. What is the mean number of pennies it held?

↑ Pennies held



- Folded bridge trials: 21, 20, 22, 25 pennies
- Same card type, gap, tape, and stop rule each trial
- Mean = total $\div$ number of trials
- Gap: 15 cm; one 5×8 in card per trial

1. Add the four trials.

2. Divide the total by the number of trials.

A blank sheet of graph paper with a grid pattern. The grid consists of 10 columns and 10 rows of squares. The paper has rounded corners and a light gray border.

3. Which trial is farthest from the mean, and by how much?

TRY IT • The flat bridge was tested four times: 8, 9, 7, 8 pennies. What is its mean?

Name _____ Date _____

LEVEL 1



Use the clues to cross out unfair plans until one plan is left.

Testing question: Does ramp height change how far a toy car rolls? Each plan rolls a car from a 10 cm ramp and then from a 20 cm ramp. Only one plan is a fair test.

FAIR TEST RULE: CHANGE ONLY THE THING YOU ARE TESTING

Plan	Car	Floor (10 cm ramp, then 20 cm ramp)	Release
Plan A	same car	tile, then tile	let go, then let go
Plan B	same car	tile, then carpet	let go, then let go
Plan C	two different cars	tile, then tile	let go, then let go
Plan D	same car	tile, then tile	let go, then pushed

1. Clue 1 (same car): cross out plans that use different cars.

[illegible]

2. Clue 2 (same floor): cross out plans that change the floor.

[illegible]

3. Clue 3 (same release): cross out plans that change the release, then name the fair plan.

TRY IT • You want to test whether floor surface changes distance. What must stay the same, and what changes?

Name _____ Date _____

LEVEL 2



Use the test evidence to rule out redesign ideas until one is left.

Tower Version 1 failed the paper-fan test. The team may change only one thing for Version 2. Which change does the evidence support?

CANDIDATES — CROSS OUT AS YOU GO

Candidate	C1	C2	C3
Non-slip pads under the base			
Triangle braces at joints			
Taller top section			
Heavier top cap			

EVIDENCE TO USE

- Version 1: 40 cm tall, 16 straws
- Paper-fan test: fan waved 5 times from 30 cm away, 3 trials
- Result: bent at the straw joints, so the top leaned, in 3 of 3 trials
- Base did not slide in any trial
- Height criterion (at least 40 cm) already met
- Rule: change one thing per redesign
- Version 2 will get the same fan test

1. Rule out the idea that fixes a problem that did not happen.

2. Rule out the idea that adds height the criteria do not need.

[illegible]

3. Rule out the idea that makes tipping worse, then name the redesign.

TRY IT • A different team's tower stood straight in 4 of 4 fan trials, but its base slid in 3 of the 4 trials. Its height already meets the criterion. Which one thing should its next version change, and why?

Name _____ Date _____

LEVEL 1



Find the range (highest minus lowest) to judge consistency.

The same tester released two paper spinners from the same marked height. A partner counted spins before landing on the first three drops of each design. Which design gave more consistent results?

SPINS (FULL TURNS OF A MARKED BLADE) COUNTED BY A PARTNER

Design (blades)	First	Second	Third	Highest	Lowest	Range
A (short)	9	12	10			
B (long)	11	11	12			

RULES

Range = highest value - lowest value

Same release height and same tester for every trial

1. Find the highest and lowest spins for Design A.

2. Subtract to find Design A's range, then find Design B's range.

A blank sheet of graph paper with a grid pattern. The grid consists of 10 columns and 10 rows of squares. The paper has rounded corners and a light gray border.

3. Which design gave more consistent results?

TRY IT • Design C spun 7, 13, and 10 times. What is its range, and how does it compare?

Name _____ Date _____

LEVEL 3



Decide which conclusion the evidence supports. Then plan a fairer test.

After Version 1, a teammate built a Big Boat that changed two things at once. It held more pennies. Which conclusion does the evidence actually support?

CONCLUSIONS – CROSS OUT

Conclusion	C1	C2
Taller sides caused the gain		
Bigger foil caused the gain		
Big Boat holds more; cause unclear		
Big Boat holds fewer		

EVIDENCE TO USE

- Version 1: 15 cm foil square, 1 cm sides; trials 24, 25, 26 pennies
- Big Boat: 20 cm foil square, 3 cm sides; trials 39, 40, 41 pennies
- Changed: foil size AND side height
- Same tub, water level, and penny-adding method
- Investigation rule: one 15 cm square per boat, one change per version

1. Use the trials to rule out the conclusion that disagrees with the data.

[illegible]

2. Explain why single-cause claims are not supported.

[illegible]

3. Name the supported conclusion and design the next fair test.

TRY IT • Another team's boat held 22, 23, 24 pennies. They changed only one thing, heavier foil, and it then held 27, 28, 29. What can they claim, and why?

2. Index-Card Bridge: Flat vs. Folded

LEVEL 1

The folded bridge held 63 pennies in total. It held more than the flat bridge in every trial.

WORKED REASONING • Folded bridge: $21 + 20 + 22 = 63$. Flat bridge: $8 + 9 + 7 = 24$. Compare trial by trial: $21 > 8$, $20 > 9$, and $22 > 7$. The folded design won all three trials, so the result repeated.

WATCH FOR • Some learners compare only Trial 1. A single trial could be lucky or unlucky. The claim is stronger because the folded bridge won every repeated trial.

TRANSFER • $15 + 17 + 16 = 48$ pennies. It ranks between the flat bridge (24) and the folded bridge (63).

3. Folded Bridge: Finding the Mean

LEVEL 2

The mean is 22 pennies. Trial 4 (25) is farthest from the mean, 3 pennies above it.

WORKED REASONING • Total: $21 + 20 + 22 + 25 = 88$. Mean: $88 \div 4 = 22$. Distances from the mean are 1, 2, 0, and 3, so Trial 4 is farthest.

WATCH FOR • Some learners divide by 3 because the earlier test had 3 trials. Always divide by the number of trials actually used, which is 4 here.

TRANSFER • $(8 + 9 + 7 + 8) \div 4 = 32 \div 4 = 8$ pennies.

6. Ramp Roller: Pick the Fair Test

LEVEL 1

Plan A

WORKED REASONING • Clue 1 (same car) removes Plan C, leaving A, B, and D. Clue 2 (same floor) removes Plan B, leaving A and D. Clue 3 (same release) removes Plan D, leaving A. Plan A changes only the ramp height.

WATCH FOR • Some learners think that changing more things gives more information. If two things change, you cannot tell which one caused the difference in distance.

TRANSFER • Keep the same car, the same ramp height, and the same let-go release. Change only the floor surface, for example tile versus carpet.

13. Straw Tower: Choose the Next Redesign

LEVEL 2

Triangle braces at joints

WORKED REASONING • The base never slid, so non-slip pads would fix a problem that did not happen. Height is already met, and a taller top gives the wind more to push on. Extra weight high on the tower may worsen leaning or tipping, and it does not brace the bent joints. Bending at the joints is the observed failure, so triangle braces at the joints target it directly.

WATCH FOR • Some learners change several things at once to be safe. Then, if Version 2 passes, nobody knows which change worked.

TRANSFER • Change only the base, one feature at a time, to reduce sliding, such as spreading the legs farther apart on the base. Use only the listed materials, keep within the 20-straw limit, and do not attach the tower or base to the table. Sliding occurred in 3 of 4 trials while the tower stayed straight in all four, so keep the other features the same and repeat the same four fan trials.

15. Paper Spinner: How Steady Are the Results?

LEVEL 1

Design A has a range of 3 spins. Design B has a range of 1 spin, so Design B is more consistent.

WORKED REASONING • Design A: highest 12, lowest 9, so $12 - 9 = 3$. Design B: highest 12, lowest 11, so $12 - 11 = 1$. The smaller range means the results stayed closer together, so Design B is more consistent.

WATCH FOR • Some learners think the design with the single biggest number is the most consistent. Consistency is about how close the trials are to each other, not about the top score.

TRANSFER • $13 - 7 = 6$. Design C is the least consistent of the three designs.

21. Foil Boat: What Can We Really Claim?

LEVEL 3

Big Boat holds more; cause unclear

WORKED REASONING • Every Big Boat trial (39 to 41) is above every Version 1 trial (24 to 26), so 'Big Boat holds fewer' is ruled out. Two variables changed together, so the data cannot separate the effect of taller sides from the effect of bigger foil. Both single-cause claims are ruled out. Next fair test: keep the 15 cm square, change only the fold (3 cm sides instead of 1 cm), and run 3 trials. That fair test is the team's Version 2, which held 30, 31, 32 pennies.

WATCH FOR • Some learners credit the change they believe in most, such as taller sides. When variables change together, they are confounded, and only a one-variable test can separate them.

TRANSFER • The middle value rose from 23 to 28, a gain of $28 - 23 = 5$ pennies, and every new trial (27 to 29) is above every old trial (22 to 24). Heavier foil was the only change, so they can claim it likely caused the gain.