

Design a Produce Bag: Criteria First, Then Build and Revise

Investigation question: What criteria and constraints, including what happens to the bag after use, must a produce bag for the school garden stand meet, and which combination of natural and synthetic materials best meets them within a budget of fifteen material tokens?

Engineering design challenge

Groups of 4

2 sessions

Setup 10 · Activity 85 · Cleanup 10 min

MS-ETS1-1 · practice

MS-ETS1-2 · practice

MS-PS1-3 · practice

Name _____

Group _____

Date _____

Your role today

- ☐ **Design lead:** Runs the criteria and constraints discussion, makes sure every criterion has a number or a clear test, and keeps the group within the token budget.
- ☐ **Materials tester:** Runs the strip and drop tests the same way on all six materials and calls out the results.
- ☐ **Builder:** Cuts, folds, tapes and ties the bag according to the plan; records the bill of materials and the token total.
- ☐ **Test engineer and recorder:** Loads the bag, runs the walk and rain tests, scores every criterion as met or not met with evidence, and leads the revision.

Safety

- Scissors only for cutting; no craft knives. Cut on the desk, away from fingers, and keep scissors closed when not in use.
- The 1 kg load is a sealed water bottle: test over the floor or a low tray, keep feet clear, and never swing or drop a loaded bag toward anyone. If a bag fails, the bottle falls a short distance onto the floor, not onto a foot.
- Water on hard floors is a slip hazard; keep the rain test over the tray, mist rather than squirt, and wipe spills at once.
- Reused plastic food bags must be washed and dried before use; do not use bags that held raw meat.
- No hot glue, staples or wire; tape and string only.

Procedure

1. Session 1, define first. Read the problem: the school garden stand needs a bag that carries 1 kg of produce 20 m to a car, keeps the produce dry in a light rain, and can be dealt with responsibly at this school after use. Before touching materials, write at least three criteria, each with a number or a clear test (for example 'holds 1 kg for a 20 m walk without tearing'; 'after ten sprays of mist, the paper towel inside stays dry'; 'every part of the bag can be recycled, composted or reused at this school'). At least one criterion must say what happens to the bag after use.

2. List at least three constraints: the 15-token budget, the menu of materials, 25 minutes to build in session 2, tape and string only, and anything else that limits you. Record both lists in the criteria and constraints table.
3. Test the materials. For each of the six materials, clip a dry strip at the top, hang the 200 g mass from the bottom for 30 s, and record holds or tears. Then soak a second strip in the tray for 60 s, lift it, hang the same mass for 30 s, and record. Finally place one drop of water on a flat piece and record how long it takes to soak in, up to 120 s.
4. Read the material fact cards and fill in the origin (natural resource or synthetic, and what it came from) and the 'what happens here' column of the material table. Mark each material's token price.
5. Plan. Choose the materials for the bag body, any lining or coating, and the handles. Sketch the bag in the drawing box with dimensions, and fill in the bill of materials. The token total must be 15 or less; if it is not, change the plan, not the budget. Predict in q1 which criterion your bag is most likely to miss.
6. Session 2, build. Set a 25-minute timer. Build the bag exactly as planned; if you change anything, record it on the bill of materials. The bag must have an opening wide enough for the bottle and at least one handle or tie.
7. Load test: place the folded paper towel in the bag, then the 1 L bottle. Lift the bag by its handle and hold it for 10 s. Record holds or fails.
8. Walk test: carry the loaded bag by its handle along the 20 m course at a normal pace. Record whether the bag arrives intact, and describe any stretching, tearing or sagging.
9. Rain test: at the rain station, give the loaded bag ten sprays of mist from about 30 cm, then carry it another 20 m. Open the bag and check the paper towel: dry, damp or wet. Record any tears or weakening.
10. Score your bag against each of your own criteria: met or not met, with the evidence. Then check it against the constraints: tokens used, time, materials.
11. Compare. Walk the room and look at two other groups' bags and scores. In the comparison table, record one feature from another design that met a criterion yours missed, or that met it more cheaply.
12. Revise. Choose one change: either rewrite a criterion that turned out to be vague or incomplete (as engineers did when plastics filled landfills), or change one design feature using what another group showed. Write the revision and the evidence for it. If time allows, rebuild the changed part and rerun the test it was meant to fix. Then answer the analysis questions individually.

Record your observations

Lab 3 recording sheet: Design a produce bag

Session 1: fill in the criteria and constraints table, the material test table and the plan before you build anything. Session 2: fill in the bill of materials as built, the test results, the comparison and the revision.

Criteria and constraints (at least three of each; every criterion needs a number or a clear test, and one must be about what happens after use)

Criteria: what a successful bag must do	How we will test it	Constraints: limits we must work within	Why it limits us

Material fact cards (teacher prints; the 'what happens here' lines describe a teaching-scenario school unless your teacher has replaced them with local facts)

Card 1

KRAFT PAPER. Origin: wood from trees, a renewable resource when forests are replanted. Process: wood chips are cooked with chemicals to free the cellulose fibers, which are pressed into sheets; the fibers are not chemically changed into a new substance, so the paper is a processed natural material. Properties: strong when dry, loses most of its strength when wet, tears once a tear starts. After use: recyclable with paper and cardboard; breaks down in a garden compost pile within months. What happens here: the school's paper recycling bin and the garden compost bin both take it. Price: 2 tokens per sheet.

Card 2

NEWSPAPER. Origin: wood fiber, much of it recycled from used paper. Process: the same pulping and pressing as kraft paper but with shorter, weaker fibers and no strengthening step. Properties: weak when dry, almost no strength when wet, absorbs water instantly. After use: recyclable with paper; composts fast. What happens here: the school's paper recycling bin and the garden compost bin both take it. Price: 1 token per sheet.

Card 3

COTTON MUSLIN. Origin: fibers from the cotton plant, a renewable crop that needs a lot of water and often pesticides to grow. Process: fibers are spun into thread and woven; the cellulose is not chemically changed, so cotton is a natural material (bleaching and dyeing use chemicals but do not change the fiber itself). Properties: strong wet or dry, absorbs water quickly, washable, reusable for years. After use: can be washed and reused many times; eventually breaks down in a compost pile over months to a year. What happens here: the garden stand will wash and reuse cloth bags; the garden compost bin takes worn-out cotton. Price: 5 tokens per 30 cm square.

Card 4

POLYESTER FABRIC. Origin: petroleum and natural gas, nonrenewable resources. Process: refining and cracking give small molecules that chemical reactions join into long PET polymer chains; the melted polymer is drawn into fine filaments and woven. Properties: strong wet or dry, dries fast, sheds water from a drop for a while but a woven fabric lets water seep through under pressure, does not rot or weaken when wet. After use: washable and reusable for years; does not biodegrade; each wash sheds tiny plastic fibers into wastewater; textile recycling is limited. What happens here: the garden stand will wash and reuse cloth bags; a worn-out polyester bag goes to the landfill. Price: 8 tokens per 30 cm square.

Card 5

PLASTIC FILM (polyethylene, from reused food bags).
 Origin: petroleum and natural gas. Process: cracking produces ethylene, and polymerization joins ethylene molecules into long polyethylene chains that are melted and blown into thin film. Properties: very strong for its weight, waterproof, stretches before it tears, cheap. After use: does not biodegrade and lasts for decades in a landfill; thin film jams the machinery at sorting plants, so most curbside programs refuse it and it must go to a store drop-off bin; loose film is easily blown into waterways, where animals mistake it for food. What happens here: not accepted in the school's recycling bins; the nearest store drop-off bin is 2 km away; otherwise it goes to the landfill. Price: 2 tokens per piece.

Card 6

WAX PAPER. Origin: wood fiber coated with paraffin wax, which is separated from petroleum (some brands use soybean wax instead). Process: pulped paper is run through melted wax, a physical coating, not a chemical change of the paper. Properties: sheds water from the surface, moderately strong dry, keeps some strength wet, creases and cracks at folds. After use: the wax coating keeps it out of paper recycling, and paraffin-coated paper does not reliably break down in compost; it usually goes to the trash. What happens here: trash to the landfill. Price: 2 tokens per sheet.

Material test table

Material	Dry strip holds 200 g for 30 s? (yes/no)	Wet strip holds 200 g for 30 s? (yes/no)	Drop soak-in time (s) or 'beads'	Natural or synthetic, and from what resource	What happens to it after use here	Tokens
Kraft paper						
Newspaper						
Cotton muslin						
Polyester fabric						
Plastic film						
Wax paper						

-  Sketch your bag design with dimensions in cm. Label the body material, any lining or coating, the handle material, and where the tape and string go.



Bill of materials (as planned, then as built; total must be 15 tokens or less)

Material or item	Quantity planned	Tokens planned	Quantity actually used	Tokens actually used
Total				

Test results and scoring against our own criteria

Test or criterion	Result (what happened)	Criterion met? (yes/no)	Evidence
Load test: 1 kg held 10 s			
Walk test: 20 m			
Rain test: towel dry/damp/wet; bag intact?			
End-of-life criterion: every part reused, recycled or composted here?			
Other criterion (write it)			

Comparison with two other groups' bags

Group	Main body material	Tokens used	Which tests passed	One feature that met a criterion ours missed, or met it more cheaply

1. Before building: which of your criteria is your bag most likely to miss, and why?

2. Our revision: we changed (a criterion / a design feature) from ___ to ___ because the evidence showed _____. If we reran a test, the result was _____.

Analysis questions

3. Using your material test table, explain the trade-off between wet strength and what happens after use. Which materials were strong wet, and where do they go after use at this school? Which were easy to recycle or compost, and how did they do wet?

4. Which material did the 15-token budget rule out or limit for your group? Did the constraint make your design worse, or did it push you toward a better combination? Give the token arithmetic.

5. A classmate says, 'The plastic film bag held the most, cost the least and kept the towel dry. Where it goes afterward is not the bag's job, so it wins.' Respond using the criteria your group wrote and the plastics story from the lesson.

6. For the main material of your bag, write the full trace: the natural resource, the process that turned it into the material (and whether that process was a chemical change), the property you chose it for, and what will happen to it after use at this school.

7. Which criterion did your group revise, or which design feature did you change, after the tests? What evidence forced the change, and how is this like what engineers did when plastics began filling landfills?

8. California banned thin plastic checkout bags in 2016 but allowed thicker 'reusable' plastic bags; evidence later showed most of those were used once too, and from 2026 no plastic carryout bags are allowed at grocery checkouts. Place each event on the design cycle (define, design, gather evidence, find a new problem, revise), and say what criterion was missing or too vague the first time.
