

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

Scientific purpose

Groups design, build and test a bag that will carry one kilogram of produce from the school garden stand to a car, including through a light rain, and that can be dealt with responsibly at this school after use. Before building, each group writes testable criteria and constraints, tests six candidate materials (kraft paper, newspaper, cotton muslin, polyester fabric, plastic film and wax paper) for wet and dry strength and water resistance, reads a fact card on where each material comes from and where it ends up here, and chooses materials within a fifteen-token budget. In session two they build, load-test, rain-test, compare prototypes across the class and revise at least one criterion or the design in light of evidence, repeating the loop the lesson describes for plastics.

Why this helps students with this chapter

Students meet the plastics story as history: a material that met its criteria and then caused a problem nobody had written down. Building a bag with a strong, cheap, waterproof plastic film on the menu reproduces the temptation, and having to write an end-of-life criterion before building, then score the bag against it, reproduces the revision. Testing materials wet shows why paper lost to plastic in the first place, and comparing prototypes shows that the best design is usually a combination, not a single material.

Standards connections

MS-ETS1-1 (practice, defining criteria and constraints with precision, including impacts on people and the environment): Students write their own criteria with numbers and tests, including an end-of-life requirement tied to the school's real facilities, and list constraints (token budget, menu, time), then use them to judge their own bag; the problem is classroom-sized, so this builds toward the PE rather than fully assessing it.

MS-ETS1-2 (practice, evaluating competing designs against shared criteria): Groups test their own bag and compare it with other groups' bags on the same load, walk and rain tests, then combine features that worked into a revised design.

MS-PS1-3 (practice, using information about the origins and end-of-life of synthetic and natural materials in a decision): The material fact cards give the natural resource, process and local end-of-life fate of each candidate; students must use that information in the design, which connects the engineering strand to the lesson's core idea that synthetic materials come from natural resources and affect society.

Roles (rotate each session)

- **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.

Materials

Item	Quantity	Per	Note
Kraft paper (brown wrapping or grocery-bag paper), sheets about 30 cm by 40 cm	4 sheets	group	2 tokens per sheet. Flattened paper grocery bags work.
Newspaper, full sheets	6 sheets	group	1 token per sheet.
Cotton muslin, 30 cm by 30 cm squares	2 squares	group	5 tokens per square. Old cotton T-shirts or pillowcases, cut up, are fine.
Woven polyester fabric, 30 cm by 30 cm squares	2 squares	group	8 tokens per square. Old polyester shirts, lining or umbrella fabric; check the label.
Plastic film cut from reused bread bags, produce bags or packaging, pieces about 30 cm by 40 cm	3 pieces	group	2 tokens per piece. Wash and dry food bags first.
Wax paper, sheets about 30 cm by 40 cm	3 sheets	group	2 tokens per sheet.
Cotton string	3 m	group	1 token per meter.
Masking tape	1 roll shared by two groups	class	1 token per 30 cm; the builder measures each piece against a ruler mark on the desk.
Scissors and a 30 cm ruler	1 each	group	
Test strips of each of the six materials, 3 cm by 15 cm, for the strength test	2 of each (one dry, one wet)	group	Cut ahead of time; these do not count against the token budget.
Binder clip and a 200 g test mass (a bag of washers, or a small bottle holding 200 mL of water)	1 set	group	
Dropper and a cup of water for the drop test; a shallow tray for soaking strips	1 set	group	

Sealed 1 L water bottle (about 1 kg) as the produce load, plus a folded dry paper towel to stand in for produce that must stay dry	1 each	group	
Spray bottle of water set to mist, for the rain test	2	class	
Stopwatch, a 20 m walking course marked with tape, and the recording sheet	1 set	group	

Estimated cost: 10 to 18 per class, less with donated fabric and bags (an estimate; Estimate. A quarter yard of muslin (about \$3), polyester squares from donated garments, one roll of wax paper (about \$4), kraft paper from grocery bags, newspaper, string (about \$3), masking tape and spray bottles from stock. Water bottles and washers are reused.)

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.

Teacher preparation and setup

1. Cut and bundle a materials kit per group with the token price written on each bundle; the token prices are the constraint, so they must be visible. Cut the test strips separately and label them by material.
2. Run the strip test yourself: clip a dry strip at the top, hang the 200 g mass from the bottom with a second clip for 30 s; then soak a second strip for 60 s and repeat. Note which materials fail wet; newspaper and often kraft paper tear, which is the result the lab counts on.
3. Mark a 20 m walking course in the hallway or along the room with tape, and set up a rain station: a tray on the floor, a spray bottle, a towel.
4. Print one material fact card set per group from the recording sheet, and write a replacement for the 'what happens here' lines if your school's recycling, composting and drop-off facts differ; tell students which lines are local and real.
5. Post the design cycle from the presentation (define, design, use and gather evidence, find new problems, revise) where groups can see it, and decide the two-session split: session 1 is define, test materials and plan; session 2 is build, test, compare and revise.

Investigation design

Independent variable The materials chosen for the bag body, lining and handles, and the construction the group designs

Dependent variable	Whether the bag meets each criterion: load held, 20 m walk survived, paper towel dry after the rain test, and the end-of-life fate of every part at this school; plus tokens spent
Controlled	Same 1 kg load and paper towel for every bag; Same 20 m course at a normal walking pace; Same ten sprays of mist from 30 cm; Same 15-token budget and the same material menu and prices; Same 25-minute build time
Trials	One full test sequence per bag (load, walk, rain), then one rerun of a single test after the revision if time allows; the class compares results across all bags.
Comparison	Each bag against its own group's criteria, and bags across the class on the same tests and token totals.

Student 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.

Expected observations

- Strip test: all six materials hold 200 g dry except newspaper, which often tears at the clip; wet, newspaper always fails and kraft paper usually fails or stretches badly, while muslin, polyester and plastic film hold, and wax paper usually holds but may crack at a fold.
- Drop test: newspaper and muslin soak a drop in within seconds, kraft within a minute, wax paper and plastic film bead for the full 120 s, and polyester beads for a while before seeping.
- Bags: muslin and polyester bags pass the load and walk tests easily; kraft bags pass dry and often fail or soften after the rain test unless the bottom is lined; newspaper bags fail the load test unless several layers are folded; plastic film bags pass all three physical tests and score 'not met' on an honest end-of-life criterion at the scenario school; wax-paper bags keep the towel dry but tear at taped seams under load.
- Token totals: most groups spend 12 to 15 tokens; a group wanting a two-square polyester bag finds it costs 16 before handles and must combine materials.
- Revisions: the most common criterion rewrite is from 'can be recycled' to 'can be recycled or composted at this school'; the most common feature change is adding a water-resistant bottom panel to a paper bag or switching handles from paper to string.

Likely difficulties

- Groups want to build before defining; hold the materials kit until the criteria table has numbers and an end-of-life criterion.
- Students write 'eco-friendly' or 'biodegradable' as the end-of-life criterion; send them to the fact cards and ask what the school can actually do with each material.
- The strip test gives mixed results if the clip crushes the wet paper or the mass is jerked; hang the mass gently and clip across the full strip width.
- Tape is used by the meter and the token count is ignored; have the builder mark 30 cm on the desk edge and record every piece.
- Groups treat the plastic-film bag's failure on the end-of-life criterion as unfair; the debrief and q5 make the point that they wrote the criterion before they built, which is exactly the lesson.
- Groups revise nothing because their bag passed everything; require every group to rewrite at least one criterion more precisely even when the bag passed, or to name one feature they would borrow.

Structured debrief

1. Post every group's criteria. Sort them as a class into testable and not yet testable, and rewrite two vague ones together ('strong' becomes 'holds 1 kg for 20 m'). Then find the end-of-life criteria: the groups that wrote 'can be recycled' versus 'can be recycled at this school' usually scored their bags differently, and that gap is the lesson.
2. Put the material test results on the board. Nearly every class finds that the materials that stayed strong wet (plastic film, polyester, muslin) include the two that go to the landfill or need a drop-off bin here, while the materials that recycle and compost easily (newspaper, kraft) failed wet. Name this as the exact trade-off that made plastics win in the first place.
3. Compare designs. The strongest bags that also meet an end-of-life criterion at this scenario school are usually muslin bodies with string handles (reusable, composts when worn out) or kraft bodies with a wax-paper or muslin bottom panel; plastic-film bags pass every physical test and fail the end-of-life criterion unless the group planned the drop-off trip. Ask which features groups borrowed in the comparison step; combining features is ETS1.B in action.
4. Walk the design cycle with two or three groups' revisions. Groups that rewrote a criterion did what the plastics engineers did; groups that changed a feature did what PLA's developers did. Both are legitimate; the evidence must be named either way.
5. Close with q8: the state's first bag law met its stated criterion (fewer thin bags) and created a new problem (thick bags used once). Ask what criterion a lawmaker should have written in 2016, and whether 'reusable' was a property of the bag or a behavior of the shopper.

Recording sheet: what students fill in

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.

Answer: A labeled sketch with the body material, any lining or bottom panel, the handle material, tape and string locations, and dimensions in cm large enough to hold the bottle (roughly 15 cm by 25 cm or larger).

Why: Grade for a buildable plan that matches the bill of materials, not for drawing quality.

- Body, handle and any lining labeled with materials
- Dimensions in cm
- Matches the bill of materials

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?

Answer: Group-specific. A reasonable answer names a criterion with a reason, for example 'the rain test, because kraft paper lost its strength wet in the strip test' or 'the end-of-life criterion, because our handles are plastic film.'

Why: A prediction tied to the material tests shows the tests informed the plan.

- Names one of the group's own criteria
- Gives a reason from the material tests or fact cards

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

Answer: Group-specific. Example: 'We changed the criterion from "can be recycled" to "every part can be recycled, composted or reused at this school" because the evidence showed our plastic-film handles cannot go in the school's bins. We replaced the handles with string and reran the load test: held.' Or: 'We changed the design from a plain kraft body to a kraft body with a wax-paper bottom because the rain test left the towel damp; the rerun kept it dry.'

Why: The revision must name evidence, and the rerun result if done. Either a criterion rewrite or a design change earns full credit.

- States what changed, from what to what
- Names the evidence (a test result or another group's bag)
- Reports the rerun result or says it was not rerun

Analysis questions: answer key

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?

Answer: Strong wet: plastic film, polyester and muslin held 200 g after soaking. Of these, plastic film goes to the landfill or a drop-off bin 2 km away, and polyester goes to the landfill when worn out; only muslin is reused here and composts eventually. Easy to recycle or compost here: newspaper and kraft paper, both of which failed the wet strip test. So the materials that are easiest to deal with afterward are the ones that fail in the rain, and the ones that survive the rain are the hardest to deal with afterward; muslin is the one material that does reasonably well on both, at a higher token price.

Why: This trade-off is the lab's central finding and mirrors why plastics replaced paper. Values from the table are required.

- Names the wet-strong materials and their end-of-life fate here
- Names the recyclable or compostable materials and their wet results
- States the trade-off and identifies muslin as the compromise

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.

Answer: Example: 'Polyester. Two squares cost 16 tokens, over the 15 limit before handles, so a whole polyester bag was ruled out. We used one polyester square (8) as the body plus kraft paper (2) for the top and string (1) for handles, 11 tokens, which kept the bag within budget and made more of it recyclable. The constraint pushed us toward a combination that scored better on end of life than an all-polyester bag would have.'

Why: Token arithmetic must be shown; either conclusion (worse or better) earns credit if argued from the design.

- Names the material limited by the budget with the arithmetic
- Explains the effect on the design with a reason

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.

Answer: The group wrote an end-of-life criterion before building, so where the bag goes afterward is part of what the bag must do, by the group's own definition of success; a design that fails any criterion is not the winner even if it leads on the others. The plastics story shows why: the first plastics met every criterion their designers wrote, which did not include what happens after use, and the result was landfills filling and animals eating plastic. Engineers then added the missing criterion rather than declaring the old plastics winners. The plastic-film bag can still win if the group plans and counts the trip to the store drop-off bin, which would make it meet the criterion at this school.

Why: Tests whether students apply their own criteria consistently and connect to ETS1.A revision.

- Points to the group's written end-of-life criterion
- Connects to the plastics story (criteria that left out end of life)
- Does not simply dismiss plastic film; notes what would make it meet the criterion

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.

Answer: Example for cotton muslin: resource, the cotton plant (renewable, water-hungry); process, spinning and weaving, which are physical changes, so the fiber is a natural material; property chosen, strong wet and dry; after use, washed and reused at the garden stand, and composted in the garden bin when worn out. Example for plastic film: resource, petroleum and natural gas; process, cracking to ethylene and polymerization into polyethylene, both chemical changes, so it is synthetic; property, waterproof and strong for its weight; after use, not accepted in the school's bins, so a drop-off trip or the landfill.

Why: The trace must identify whether the process was a chemical change; this is the natural-versus-synthetic test from the lesson applied to the group's own choice.

- Resource named
- Process named and identified as chemical or physical
- Property and local end-of-life fate stated

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?

Answer: Group-specific. Example: 'We revised "keeps produce dry" to "after ten sprays of mist, the towel inside is dry and the bag still holds 1 kg," because our kraft bag kept the towel dry but tore at the bottom afterward and the old criterion did not cover that. The plastics engineers did the same thing: their material met the criteria they had written, evidence showed a problem the criteria had not covered, and they added a criterion instead of pretending the design had succeeded.'

Why: Looks for a change driven by named evidence and an explicit parallel to the revision step in the design cycle.

- Names the revision
- Names the evidence that forced it
- Draws the parallel to revising criteria after plastics caused new problems

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.

Answer: Define: the goal was fewer plastic bags in litter and landfills. Design: in 2016 the state banned thin single-use bags and allowed thicker bags labeled reusable. Gather evidence: after years of use, data showed shoppers used the thick bags once and threw them away, and plastic bag waste did not fall as intended. Find a new problem: the thick bags were heavier plastic used just as briefly. Revise: a 2024 law removed plastic carryout bags of any thickness from checkouts starting in 2026. The missing or vague criterion was about behavior and outcome, not the bag: 'reusable' described what the bag could do, not whether people would reuse it; a testable criterion would have been something like 'the total mass of plastic bag waste per shopper falls by a stated amount within two years.'

Why: Checks transfer of the design cycle to a real policy. Students only need the structure and the idea that 'reusable' was a property, not an outcome.

- Places the events on the five cycle steps in order
- Identifies that 'reusable' was not a testable outcome criterion
- Proposes a more precise criterion

Individual evidence of learning

Each student submits their own criteria and constraints table, material test table, sketch, bill of materials, scoring table, comparison table and individual answers to q1 through q8. The criteria table with the test column and the end-of-life row, together with q5 and q7, are the primary evidence for MS-ETS1-1 practice; q3 and q6 are the evidence for connecting material origins and end of life to the design decision.

Assessment criteria

Criterion	Proficient looks like
Criteria defined with precision, including end of life	At least three criteria, each with a number or clear test, written before building, including one about what happens to the bag after use at this school, and used to score the bag afterward.
Constraints identified and respected	At least three constraints listed with how each limited the design; the bill of materials totals 15 tokens or less and matches what was built.
Evidence-based design and revision	Material choices are justified from the strip, drop and fact-card results; the bag is scored honestly against the group's criteria; one revision is tied to named evidence from the group's own tests or another group's bag.
Material origins and impacts	Traces the main material from a natural resource through a process (identified as a chemical change or not) to a property and an end-of-life fate at this school, and explains the strength-versus-end-of-life trade-off with test values.

Accessibility adaptations

- Provide criteria sentence frames ('The bag must ___ when ___, tested by ___') and a word bank for constraints (tokens, time, materials, tape, string).

- Let a partner do the cutting and taping while a student with limited fine-motor control directs the design, records results and runs the stopwatch; the design and scoring roles carry the learning.
- Print the fact cards in large type with the 'what happens here' line in bold, and offer a bilingual word list for criterion, constraint, renewable, compost, recycle, landfill, lining and polymer.
- Accept the sketch as a labeled photo of the built bag and q5 and q7 as recorded spoken answers; for students ready for extension, add a seventh material card (a PLA-coated paper) and ask them to decide whether it changes the design at this school.

Low-cost alternative

Use only newspaper, grocery-bag kraft paper, reused plastic food bags and cut-up cotton T-shirts, with the same token prices, and skip polyester and wax paper. A 500 mL bottle can stand in for the load if bags are smaller. Replace the spray bottle with ten drops from a dropper spread over the bag.

Model limitations

A 20 m walk, ten sprays of mist and a 1 kg bottle stand in for real use, rain and produce; a bag that passes here might fail in a downpour or under a bag of potatoes. Token prices are rough stand-ins for relative cost and ignore the environmental costs the end-of-life criterion is meant to capture. The scenario school's facilities are invented; the material facts are accurate in general terms but recycling and composting rules vary by town. This activity has not been physically tested by the authors; the strip-test outcomes and bag results in the expected observations are estimates from the known behavior of these materials and should be checked in the teacher's trial run.

Teacher notes

Check every criteria table at the end of session 1 and send back any criterion without a number or test, and any group without an end-of-life criterion; the lab's evidence for MS-ETS1-1 lives there. In session 2, the most common failure is a plastic-film bag that passes everything and then argues with its own end-of-life criterion; let that argument happen and steer it with q5 rather than settling it. If a group builds a muslin bag with string handles and passes everything, push them on cost (tokens) and on the water and pesticides in cotton farming from the fact card, so that no material looks free of trade-offs. Replace the scenario 'what happens here' lines with your school's real facilities whenever you can; the lab is better with true local information.