

Shield the Frog Listener: A Noise Barrier for a Pond Sensor

Investigation question: Can your team build a shield that cuts the highway noise reaching a frog-call sensor by at least 5 decibels, while keeping the pond side open and staying within the kit budget, and which of your two designs best meets the criteria when they are compared systematically?

Engineering design challenge

Groups of 4

2 sessions

Setup 10 · Activity 85 · Cleanup 10 min

MS-ETS1-1 · practice

MS-ETS1-2 · practice

MS-LS2-2 · supports

MS-PS4-2 · supports

Scientific purpose

Biologists count frogs by recording their calls, and a population count is only useful if the recorder can hear the frogs. Students take a vague complaint ('the highway drowns out the frogs') and turn it into measurable criteria and constraints, including limits that protect the pond and the people who service the sensor. They build two shields that rely on different ideas about how sound is stopped, measure each one with a phone sound-level app from a highway position and a pond position, check every constraint, and choose between them with a weighted decision matrix. An optional third build combines the best features of both.

Why this helps students with this chapter

The lesson's engineering story, choosing a tool to monitor Yellowstone's wolves, shows that criteria and constraints decide which design is chosen, but students only read about it. Here they feel why precision matters: 'make it quieter' cannot be tested, while 'cut the highway reading by at least 5 dB and change the pond reading by no more than 2 dB' can, and the second criterion stops the obvious wrong answer of a box that silences the frogs too. Scoring two of their own designs in a matrix shows that a systematic comparison can overturn a favorite.

Standards connections

MS-ETS1-1 (practice, defining criteria and constraints precisely, including impacts on the natural environment): Students rewrite seven plain-language needs as measurable criteria and constraints with numbers, units and tests (q1), including constraints that protect the pond and allow the sensor to be serviced, before building. It is practice rather than assessment because the class then adopts shared test rules so results can be compared.

MS-ETS1-2 (practice, evaluating competing designs with a systematic process): Each team scores two of its own designs against the same criteria in a weighted decision matrix after a constraint check, and defends the choice with measured decibel changes (q2, q3). The comparison is between two classroom designs with a supplied scoring guide, so it builds toward the PE rather than fully assessing it.

MS-LS2-2 (supports, why reliable population data matters for predicting interaction effects): The shield exists so a frog population can be counted accurately; q10 asks students to name the frogs' interactions and

predict a ripple effect that would go unnoticed without good counts, connecting the design to the chapter's interaction patterns.

MS-PS4-2 (supports, sound reflected, absorbed or transmitted by different materials): Students use the idea that materials reflect, absorb or transmit sound to plan and explain their shields. This is a Grade 8 performance expectation in the California integrated sequence; here it is used qualitatively as background and is not assessed.

Roles (rotate each session)

- **Project lead:** Keeps the 20-minute build clock and the 10-credit budget, runs the constraint check, and makes sure the team's two designs use different ideas.
- **Builder:** Cuts, folds and tapes the shields with scissors and masking tape, and seals every loose piece.
- **Tester:** At the test station, checks the phone positions against the marks, starts and stops the clips at the posted volume, and keeps hands and bodies out of the sound path during readings.
- **Recorder:** Reads the sound-level app aloud, writes every reading, computes averages and changes, and fills in the decision matrix with the team.

Materials

Item	Quantity	Per	Note
Phones or tablets for the test stations: one plays the highway and frog clips, one runs a free sound-level meter app as the sensor	2 per station, 2 or 3 stations	class	School devices or the teacher's; students' own phones only with school permission. Put both in do-not-disturb mode.
Test-station mat: poster board marked with H, S and P in a straight line 30 cm apart, a 30 cm by 30 cm square centered on S, and the pond line through S at right angles to the H-S-P line	1 per station	class	
Cardboard sheets, about 30 cm by 30 cm, cut from boxes	3	group	Cut by the teacher before class.
Shoebox or small carton	1	group	
Old hand towel	1	group	
Felt or fleece square, about 30 cm by 30 cm	1	group	
Egg carton (paper or foam)	1	group	
Aluminum foil, 30 cm length	1	group	
Bubble wrap, about 30 cm by 30 cm	1	group	
Cotton balls in a zip-top bag	10	group	
Old paperback books or 1 cm stacks of magazines	2	group	
Masking tape	1 roll	group	

Scissors and a 30 cm ruler	1 each	group	
Calculator	1	group	
Recording sheet	1	student	
Ear defenders or foam earplugs	a few	class	For students who are sensitive to sound; the test levels are well below harmful levels.

Estimated cost: 10 to 20 per class, not counting phones or tablets (an estimate; Estimate. Masking tape (about \$1 a roll if not in stock), felt squares (about \$0.40 each), a bag of cotton balls (about \$2) and a roll of foil (about \$4). Cardboard, egg cartons, towels, bubble wrap, books and poster board are usually donated or recycled. Sound-level apps used here are free.)

Safety

- **Hearing:** keep the playback at the posted setting, which gives about 65 to 75 dB at the sensor, a little louder than conversation. No one puts an ear against a speaker or turns the volume up. NIOSH sets its recommended limit at an average of 85 dB over an 8-hour day; these short tests stay well below that.
- **Cutting:** students use scissors only. The teacher cuts thick cardboard with a box cutter before class. Fold the edges of foil, which can cut skin.
- **Heavy items:** stack books or magazines no higher than 15 cm, tape them so they cannot slide, and keep them clear of the phones so nothing falls on a device or a hand.
- **Devices:** phones lie flat on the table, not near its edge; no drinks at the stations. Only the tester handles the station phones.
- **No hot glue, staples or sprays.** Cotton balls and other fibers stay sealed in bags or taped down, both for tidy cleanup and because that is a design constraint.
- **Students who are sensitive to sound** can take the project-lead or recorder role away from the station or wear ear defenders. This activity has not been physically tested by the authors; pilot one station before class.

Teacher preparation and setup

1. Choose two test stations (three for a large class) as far apart as possible, such as opposite corners of the room or a hallway alcove with permission, away from fans and doors. Tape a station mat flat on a table at each one.
2. Before class, put two clips on each playback phone from a trusted source: a steady traffic-noise recording or pink noise for the highway, and a steady tone near 2,000 hertz (in the pitch range of many frog calls) or a frog-chorus recording for the pond. Download them yourself; students do not download anything.
3. Install a free sound-level meter app on each sensor device (for example the NIOSH Sound Level Meter app on iPhone; on Android, a well-reviewed free meter). Set it to A-weighting and, if it offers one, a slow response or a 10-second average.
4. Pilot each station. Place the playback phone flat on H with its speaker end toward S, and the sensor phone flat on the pond half with its microphone end at S. Raise the volume until the sensor reads 65 to

- 75 dB with no shield; tape a note of that volume setting to the phone. Check that the room reads at least 15 dB lower with nothing playing, and that one plain cardboard wall gives a drop you can see.
5. Cut the cardboard sheets with a box cutter (teacher only), pack one materials kit per group, and post the price list and the class test rules.
 6. Plan a testing rotation for session 2: each group needs about 6 minutes at a station for six measured conditions. Groups not testing score, calculate or work on the analysis questions quietly.

Investigation design

Independent variable	The shield at the sensor: none, Design A, Design B (and an optional improved design)
Dependent variable	The average sound level at the sensor in decibels with the clip played from H (highway) and from P (pond), and the change from the no-shield reading; whether each design stays standing in the bump test
Controlled	Same playback phone, clip and volume setting for every test; Same sensor phone, app settings and position, with its microphone end at S; Same distances: 30 cm from H to S and from P to S; Same reading method: three 10-second averages per condition; Same station and similar background level, recorded before each team's tests
Trials	Three readings per condition, averaged; each team measures its own no-shield readings at its own station on the same day, so changes are measured with the same phone in the same place.
Comparison	Each design's highway and pond readings against the no-shield readings taken minutes earlier; Design A against Design B in the decision matrix; every team's best design on the class chart.

Student procedure

1. Session 1. Read the design brief and the science notes on the recording sheet. As a team, complete q1: for each plain-language need, decide whether it is a criterion or a constraint and write a measurable version with a number, a unit and a test.
2. Compare your q1 table with the class test rules your teacher posts (also on the sheet). Use the class rules for testing so every team's numbers can be compared; keep any extra criteria you wrote as bonus goals.
3. Plan two designs that rely on different ideas about stopping sound (for example, one heavy, gap-free wall versus a three-sided hood lined with soft material). Sketch both from above and from the side in the drawing box, showing the H, S and P marks and the pond line, and label every material and size.
4. Price each design with the kit price list (10 credits or fewer each) and write your predicted highway drop and pond change in the design-plan table.
5. Build Design A within 20 minutes, then Design B within 20 minutes. Tape every loose piece. Label both with your team name and store them flat.
6. Session 2. At your station, the tester checks that the playback phone is at the posted volume and the sensor phone is flat on the pond half with its microphone end at S. With nothing playing, record one

background reading.

7. No-shield highway test: place the playback phone on H with its speaker toward S and start the highway clip. Wait 5 seconds, then take three readings (the app's 10-second average, or three readings 5 seconds apart). Everyone stays still and quiet and out of the line between the phones.
8. Place Design A on the highway half of the square without touching the sensor or crossing the pond line, and take three readings. Swap in Design B and take three more.
9. Pond test: move the playback phone to P with its speaker toward S, switch to the pond clip, and take three readings with no shield, three with Design A and three with Design B.
10. Bump test: with each design in place, tap the table firmly twice 20 cm away and fan it three times with a sheet of cardboard from 50 cm. Record whether it stayed standing and in place, then return the station exactly as you found it.
11. Back at your table, compute each average and each change from no shield, complete the constraint check, and score both designs in the decision matrix with the scoring guide. Write your recommendation (q2 and q3).
12. If time allows, build one improved design that combines the best features of A and B, and test it once from H and once from P. Then post your best design's highway drop and pond change on the class chart, clean up, and answer q4 to q11.

Expected observations

- These are estimates from how sound behaves, not tested values. With the playback at the posted setting, no-shield highway readings at S are about 65 to 75 dB, and a quiet room reads about 35 to 50 dB with nothing playing.
- A single flat sheet of cardboard that just blocks the line between H and S gives a drop of only about 2 to 5 dB, because sound bends over and around its edges and leaks under it.
- Taller, wider, heavier, gap-free walls (cardboard layered with a towel or a book, taped to the table) and three-sided hoods lined with towel or felt usually give about 5 to 12 dB. Foil alone and egg cartons alone do about as well as plain cardboard or worse, because they are light and full of gaps.
- With the pond side open, the pond reading usually changes by less than 2 dB, and a hood sometimes raises it by a decibel or so, because its back wall reflects pond sound toward the sensor.
- Repeated readings of the same condition differ by about 1 to 2 dB, so a 5 dB criterion is clearly measurable, but a 1 dB difference between two designs is not a real difference.

Likely difficulties

- Other teams' noise raises the background. Run tests in turns, ask for silence at the stations during the 30 seconds of readings, and have teams record background each time; a test is only trustworthy when the no-shield reading is at least 10 dB above background.
- The sensor phone gets nudged or turned between tests, which changes the reading more than some shields do. Tape an outline of the phone on the mat and check it before every reading.
- Notifications, automatic volume or a screen lock interrupt a clip. Use do-not-disturb mode and keep the clip on a loop.

- Teams build a fully closed box that crosses the pond line or touches the sensor, then argue that it is the best. Let the constraint check decide; this is the moment C2 and K3 earn their place.
- Teams weight every criterion 3, which makes the weights meaningless, or forget to multiply. Require a reason for each weight and check one row of arithmetic.
- Many students believe egg cartons are soundproofing. Let them test it; the data usually settle the question.

Structured debrief

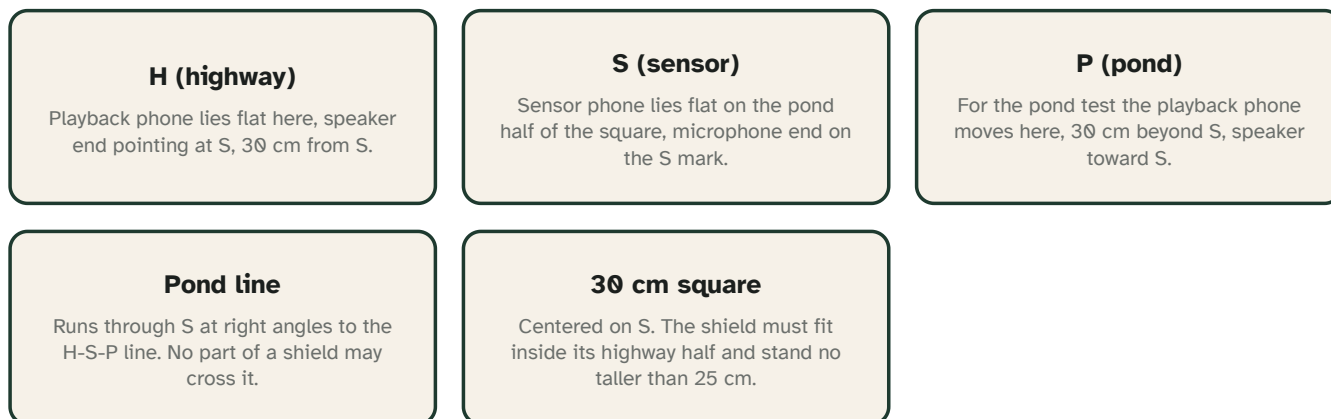
1. Build the class chart on the board: highway drop across the bottom, pond change up the side. The best designs sit far to the right with a pond change near zero. Ask what the right-hand designs share. Expect height and width beyond the line between H and S, mass (books, layered cardboard), edges taped down to the table, and a soft lining inside a hood; expect foil alone and egg cartons alone to have done little, which corrects a common belief.
2. Ask which first drafts of q1 could not be tested ('make it quieter', 'don't block the frogs') and how the class rules fixed them with numbers. Point out the two constraints that come from the natural environment (the pond line and nothing loose) and the one that comes from people (the sensor must be serviceable). That is what MS-ETS1-1 means by precise criteria and constraints that account for impacts on people and the environment.
3. Compare matrices. Did any team's favorite lose once the scores were weighted? Did two teams weight the criteria differently and pick different winners from similar data? A systematic process does not remove judgment, but it makes the judgment visible and arguable, which is the point of MS-ETS1-2.
4. Connect back to the lesson. Yellowstone's collars and Willow Pond's sensor are both tools for counting a population without disturbing it. The counts are what let managers use the interaction patterns from Labs 1 and 2: a drop in frogs could mean more insects, fewer garter snakes or herons, or a parasite spreading, and none of that can be predicted from bad data.
5. If teams built an improved design, ask which features they combined and whether the numbers improved. That combining step is the start of MS-ETS1-3, which later chapters develop.

Recording sheet: what students fill in

Lab 3 recording sheet: Shield the frog listener

The problem. Biologists track the Pacific chorus frogs at Willow Pond, an invented pond, by recording their calls. Each spring night an automatic sensor on a post at the pond's edge records the calling males, and the counts show whether the population is growing or shrinking. Last year the highway along the pond's north side was widened. On busy nights the recordings are mostly traffic, calls are missed, and the counts are too low to trust. Your team will design a shield that sits beside the sensor and cuts the highway noise reaching it, without blocking calls coming from the pond to the south, without touching the sensor, and without harming the pond. In class, a phone on the H mark is the highway, a phone with a sound-level app at the S mark is the sensor, and the P mark is the pond.

Test station layout, seen from above



H, S and P lie in one straight line, 30 cm apart.

What the science says about stopping sound — Sound is a vibration passed through the air. When it meets a material, some of it is **reflected** (bounced back), some is **absorbed** (a little of its energy becomes heat in the material), and some is **transmitted** (passes through). Heavy, dense materials transmit less sound than light ones. Any gap or crack leaks sound, so a wall should meet the table. A barrier works best when it blocks the straight line between the source and the sensor with room to spare, because sound bends around edges, and low, rumbling pitches bend around more easily than high ones. Soft, porous materials such as towels and felt absorb sound that would otherwise bounce around inside a hood.

1. Turn each need into something you can test. Mark it as a criterion (what success requires) or a constraint (a limit on what is allowed), then write a measurable version with a number and a unit, and how you will check it.

Answer: Cut the highway noise: criterion; the average highway reading at S drops by at least 5 dB compared with no shield; three readings with and without the shield. Keep the frog calls: criterion; the average pond reading at S drops by no more than 2 dB; three readings from P with and without the shield. Stay standing: criterion; does not move or fall during two firm taps and three fans with cardboard; bump test. Fit at the site: constraint; inside the highway half of a 30 cm square, no taller than 25 cm; measure with a ruler. Cost: constraint; 10 kit credits or fewer; add up the price list. Service the sensor: constraint; nothing touches the sensor and it can be lifted out without moving the shield; lift it out and check. Do no harm to the pond: constraint; no part crosses the pond line and nothing loose can blow into the water; inspect against the line and check every fiber is sealed.

Why: Criteria state what success requires and are measured; constraints limit which designs are allowed. A good row has a number, a unit and a test. The class rules are one correct version; others are acceptable if they are measurable and fit the need.

Also acceptable: Teams may classify 'stay standing' as a constraint; accept it if the test is stated. Accept other thresholds that are measurable and reasonable (for example a drop of at least 6 dB, or a stated wind or tap test), and extra environmental limits such as no shiny surfaces facing the pond or no materials that could leak chemicals into water.

- Each need classified as a criterion or a constraint with a defensible reason
- Each row has a number and a unit
- Each row names a test or check
- At least one constraint protects the pond or wildlife

Class test rules (your teacher confirms these after you draft q1) – Criteria. C1: the average highway reading at S drops by at least 5 dB compared with no shield. C2: the average pond reading at S drops by no more than 2 dB compared with no shield. C3: the shield stays standing and in place through the bump test. **Constraints.** K1: kit materials only, 10 credits or fewer per design. K2: nothing touches the sensor phone, and the phone can be lifted out without moving the shield. K3: no part of the shield crosses the pond line. K4: the shield fits inside the highway half of the 30 cm square and is no taller than 25 cm. K5: nothing loose; every cotton ball, fiber or scrap is sealed in a bag or taped down, because loose material would end up in a real pond. K6: each design is built in 20 minutes or less.

Kit price list (invented credits for budgeting practice) – Cardboard sheet, 1 credit. Shoebox or carton, 2. Hand towel, 2. Felt or fleece square, 2. Egg carton, 1. Foil, 30 cm, 1. Bubble wrap sheet, 1. Bag of 10 cotton balls, 1. Paperback book or magazine stack, 3 each. Masking tape, free (up to 2 m per design). Scissors and ruler, free.

- ✎ Sketch Design A and Design B. For each, draw a top view showing H, S, P, the pond line and the square, and a side view showing heights. Label every material and its size, and mark where you expect sound to be reflected or absorbed.

Answer: Two labeled sketches, top and side views, that show H, S, P, the pond line and the square, keep each shield on the highway half without touching the sensor, give the materials and sizes, and differ in their main idea (for example a heavy layered wall taped to the table versus a lined three-sided hood). Expected sound paths are marked: reflection off hard faces, absorption in soft linings, and the open path from P to S.

Why: The drawing is the plan that makes the two designs testably different and lets the constraint check be done before building.

- Top and side views with the station marks and the pond line
- Materials and dimensions labeled
- Both designs obey the size and pond-line limits on paper
- The two designs use different main ideas

Design plans

Design	Big idea: what should stop the sound?	Materials and credits	Total credits	Predicted highway drop (dB)	Predicted pond change (dB)
A					
B					
Improved (optional)					

Sound readings at the sensor (dB)

Test	Reading 1	Reading 2	Reading 3	Average	Change from no shield
Background, nothing playing		—	—	—	—
Highway clip at H, no shield					0
Highway clip at H, Design A					
Highway clip at H, Design B					
Pond clip at P, no shield					0
Pond clip at P, Design A					
Pond clip at P, Design B					
Highway clip at H, improved design					
Pond clip at P, improved design					

Constraint check (write yes or no; one 'no' disqualifies a design)

Design	K1: 10 credits or fewer	K2: sensor untouched and removable	K3: pond line clear	K4: fits the half-square, 25 cm or lower	K5: nothing loose	K6: built in 20 min	C3: passed the bump test
A							
B							

Scoring guide for the decision matrix — Highway drop (C1): 3 = 8 dB or more; 2 = 5 to 7.9 dB; 1 = 3 to 4.9 dB; 0 = less than 3 dB. **Pond change (C2):** 3 = no drop, or a rise; 2 = a drop of up to 1 dB; 1 = a drop of 1.1 to 2 dB; 0 = a drop of more than 2 dB. **Stability (C3):** 3 = did not move; 2 = shifted but stayed standing; 1 = needed one fix; 0 = fell. **Cost:** 3 = 6 credits or fewer; 2 = 7 or 8; 1 = 9 or 10. Give each criterion a weight from 1 to 3 and explain why; multiply each score by its weight and add.

Decision matrix

Criterion	Weight (1 to 3)	Why this weight	Design A score (0 to 3)	A: weight × score	Design B score (0 to 3)	B: weight × score
C1 highway drop						
C2 pond change						
C3 stability						
Cost						
Total	—	—	—		—	

2. Winning design: _____. Matrix totals: A ____, B _____. Winner's highway drop: ____ dB (C1 needs at least 5). Winner's pond change: ____ dB (C2 allows a drop of no more than 2). Constraints broken by the winner: _____.

Answer: Answers vary with each team's data. Check that the named winner has the higher matrix total, breaks no constraint, and that the highway drop and pond change copied here match the data table. A typical winning line: Design B, totals A 14 and B 19, highway drop 7.3 dB, pond change −0.7 dB, constraints broken: none.

Why: This is a consistency check between the data table, the constraint check and the matrix; a winner that breaks a constraint should not be named.

- Winner matches the higher total among designs that passed every constraint
- Numbers match the team's own data table

3. Write a recommendation to the Willow Pond biologists. Which design should go to the pond, and why? Use your matrix totals and at least two measured numbers, explain the result with the science of reflection, absorption and transmission, and name one constraint your design keeps that protects the frogs or the pond.

Answer: Answers vary. A strong recommendation names the design, gives its matrix total compared with the other design, quotes at least two measurements (for example 'the highway reading fell from 72.0 to 64.7 dB, a 7.3 dB drop, while the pond reading changed by only 0.7 dB'), explains why with the science (the layered wall and books are heavy and transmit little sound, the taped edges leave no gaps, the towel lining absorbs sound bouncing inside the hood, and the open pond side lets frog calls reach the sensor directly), and names a protective constraint (it stays behind the pond line and has nothing loose that could end up in the water).

Why: MS-ETS1-2 asks students to evaluate competing solutions systematically and defend the result; the defense must use the test data and the matrix, not preference.

- Names the recommended design and compares matrix totals
- Uses at least two measured numbers
- Explains the result with reflection, absorption or transmission, mass or gaps
- Names a constraint that protects the frogs or the pond

Analysis questions: answer key

4. One team's highway readings with no shield were 71, 72 and 70 dB. With its shield they were 65, 64 and 65 dB. Find both averages and the drop. Does the shield meet C1?

Answer: No-shield average: $(71 + 72 + 70) \div 3 = 213 \div 3 = 71.0$ dB. Shield average: $(65 + 64 + 65) \div 3 = 194 \div 3 = 64.7$ dB. Drop: $71.0 - 64.7 = 6.3$ dB. Yes, it meets C1, which needs at least 5 dB.

Why: Averaging three readings smooths the 1 to 2 dB wobble between readings before the comparison is made.

Also acceptable: Accept 6.3 or 6.33 dB.

- Both averages correct
- Drop computed correctly
- Correct judgment against C1

5. A rule of thumb: every 3 dB drop cuts the sound energy reaching the sensor roughly in half. About what fraction of the original highway sound energy gets through a shield with a 6 dB drop? With a 9 dB drop?

Answer: A 6 dB drop is two halvings: $1/2 \times 1/2 =$ **about one quarter** of the original sound energy gets through. A 9 dB drop is three halvings: $1/2 \times 1/2 \times 1/2 =$ **about one eighth**.

Why: Decibels are a logarithmic scale; each 3 dB step is close to a factor of 2 in sound energy (more exactly 1.995), so a modest-looking number of decibels can mean a large change in energy.

Also acceptable: Accept 25 percent and 12 to 13 percent.

- One quarter for 6 dB
- One eighth for 9 dB
- Shows the repeated halving

6. Why must the clip, the volume and every phone position stay the same for every test, and why does each team measure its own no-shield readings at its own station instead of using another team's?

Answer: They are controlled variables: if the clip, the volume or a phone's position changed between tests, the reading could change because of that and not because of the shield, so the comparison would not be fair. Each station has its own phones, room echoes and background noise, and phone microphones and apps differ by a few decibels, so a fair change can only be measured with the same phones in the same place on the same day.

Why: The test measures a change, so everything except the shield must stay the same for both readings.

- Identifies these as controlled variables needed for a fair comparison
- Explains why baselines from another station or phone are not comparable

7. One team's shield cut the highway reading by 11 dB but also cut the pond reading by 8 dB. Using the purpose of the sensor, explain why this design fails even though it was the quietest in the class.

Answer: The sensor exists to count frogs. An 8 dB drop in the pond reading means the frog calls lose almost as much as the traffic does (8 dB against 11 dB), so the calls stand out from the noise only about 3 dB better than with no shield and the counts would stay too low to trust. The design fails C2, which allows a pond drop of no more than 2 dB, and it probably crossed the pond line or closed in the sensor, breaking K3. Being quiet is not the goal; hearing frogs over the traffic is.

Why: This checks that students understand why C2 exists: a shield must improve the frog calls compared with the noise, not just lower everything.

- States that the purpose is detecting frog calls for an accurate count
- Notes that cutting both sounds leaves the calls still buried in the noise
- Identifies the failed criterion C2 (and possibly K3)

8. During one test the background reading, with nothing playing, was 60 dB because another team was testing nearby, and the shielded highway reading was 61 dB. Why can this test not show how well the shield works, and what should the team do?

Answer: The sensor can never read lower than the room's background, so with background at 60 dB a shielded reading of 61 dB mostly measures the other team's noise, not the leftover highway sound. The shield might be cutting the highway sound much more than the numbers show. The team should wait for a quiet moment and retest, making sure the no-shield reading is at least 10 dB above background.

Why: This is the measurement floor: a reading near background is dominated by background, so the true change cannot be measured.

- Explains that readings cannot fall below background
- Says the true drop is unknown and probably larger
- Proposes retesting in quieter conditions

9. Name two ways the classroom test differs from a real highway beside a real pond. For each, say whether a real shield would probably do better or worse than your test showed, and why.

Answer: Any two, with a direction: phone speakers make little low-pitched sound, while real trucks rumble at low pitches that bend around barriers more easily, so a real shield would do worse. The classroom highway is one small source 30 cm away, while a real highway is a long line of traffic coming from many angles at once, so sound would reach the sensor around the ends of the shield and it would likely do worse unless it were much wider. Wind, rain and sun would soak towels, warp cardboard and loosen tape, so performance would drop over the season. The classroom has walls that reflect sound back toward the sensor, while an open pond edge has fewer reflections, which could make a real shield do somewhat better. Frogs call from all around a real pond, not from one point.

Why: Every model has limits; judging the direction of each difference is part of evaluating whether a design will work in the real setting.

- Two specific differences between the model and the real site
- A direction (better or worse) for each
- A reason for each

10. Why do managers need trustworthy frog counts? Name two interactions that Willow Pond's chorus frogs take part in, rate each partner with +, – or 0, and predict one ripple effect on another population if the frogs declined and nobody noticed.

Answer: Managers use population counts to notice changes and predict ripple effects through a population's interactions, and a count that misses calling frogs could hide a decline. Example interactions: frogs eat insects such as midges and mosquitoes (predation: frog +, insect –); garter snakes and herons eat frogs (predation: predator +, frog –); tadpoles graze algae (predation by a plant eater: tadpole +, algae –); the chytrid fungus infects frogs' skin (parasitism: fungus +, frog –). Ripple example: if the frogs declined unnoticed, the insects they eat could increase, and garter snakes or herons that depend on frogs could decline or switch to other prey.

Why: This connects the engineering task back to MS-LS2-2: predicting the effects of a population change requires knowing its interactions and having trustworthy data on it.

Also acceptable: Accept competition between chorus-frog tadpoles and other tadpoles for algae (– –), or introduced bullfrogs eating chorus frogs (predation).

- Explains why accurate counts matter for management
- Two interactions with correct ratings for both partners
- A plausible ripple effect on another population

11. A real shield must stand outdoors through a whole spring breeding season. Write one new criterion and one new constraint you would add, each with a number.

Answer: Example criterion: after 8 weeks outdoors, the shield still cuts the highway reading by at least 5 dB. Example constraint: no material that could release chemicals or fibers into the pond; or the shield may weigh no more than 10 kg so one biologist can carry it; or it must leave a gap of at least 5 cm at ground level so frogs can move between the pond and the land, which conflicts with the no-gaps advice and would have to be traded off.

Why: A real site adds weather, time and wildlife movement, so new criteria and constraints are needed, and stating them with numbers keeps them testable.

- One criterion with a number and a unit
- One constraint with a number and a unit
- Both fit an outdoor, season-long setting

Individual evidence of learning

Each student keeps a copy of the team's q1 table, test data and decision matrix, writes their own recommendation for q3, and answers q4 to q11 individually. q1 and q11 are the evidence for defining precise criteria and constraints (MS-ETS1-1); the matrix, q2 and q3 are the evidence for systematic evaluation (MS-ETS1-2); q4, q5 and q8 show handling of decibel data; q10 links the design back to interactions and population change.

Assessment criteria

Criterion	Proficient looks like
Precise criteria and constraints	Every need in q1 is classified correctly and rewritten with a number, a unit and a test, including at least one constraint that protects the pond and one that protects how people use the sensor.
Fair testing and data	Background and no-shield readings recorded at the same station; three readings per condition; averages and changes computed correctly; only differences larger than about 2 dB treated as real.
Systematic evaluation	Constraint check completed before scoring; weights justified; matrix arithmetic correct; the recommended design is consistent with the matrix and the measured numbers.
Scientific explanation	Explains the winning design's performance with reflection, absorption and transmission, mass, gaps and the line between source and sensor.
Purpose and ecology	Explains that the shield must keep frog calls audible because the goal is an accurate population count, and connects that count to predicting effects on other populations.

Accessibility adaptations

- Students who are deaf or hard of hearing can take the tester or recorder role fully, because the sound-level app gives a visual number; the listener version in the low-cost alternative is not needed for them.
- Students who are sensitive to sound can work as project lead or recorder away from the station, or wear ear defenders; testing in turns keeps the room quiet.
- For limited fine-motor control, pre-cut cardboard panels and pre-torn tape tabs, and let the student direct the builder.
- Provide a picture checklist for the station setup and a glossary card for criterion, constraint, decibel, reflect, absorb and transmit; give an averaging template for q4 and the data table.

Low-cost alternative

With no sound-level app, run a listener test that measures what the biologists actually care about: whether frog calls can be detected. One phone plays the highway clip at H. A second student, the 'frog', sits at P and taps a pencil softly on a plastic cup ten times at random moments over 30 seconds. The listener rests one ear at S (cheek on a folded towel, other ear covered) and raises a hand for each tap heard. Count detections out of 10 with no shield and with each design; C1 becomes 'at least 3 more detections out of 10 than with no shield'. Allow a slightly larger square, because the shield must leave room for the listener's head.

Model limitations

This activity has not been physically tested by the authors; the expected decibel changes are estimates from basic sound behavior, so pilot one station before class. Phone speakers produce very little low-pitched sound, so the classroom 'highway' lacks the deep rumble of trucks, which bends around barriers more easily than higher sounds; a real shield would probably do worse than these tests suggest. The classroom highway is one small source 30 cm away rather than a long line of traffic, the room's walls reflect sound, and phones and apps can differ from a calibrated meter by a few decibels, which is why the test relies on changes measured with the same phone in the same place. There is no wind, rain or sun to weaken materials, and real frogs call from many places around a pond, not from one point.

Teacher notes

Pilot one station before the lab and post the volume setting. The key lesson is in C2: teams that silence everything should discover that they have failed the real goal, so do not warn them off fully closed boxes too early; let the constraint check and the pond test teach it. The scoring guide is supplied so matrices can be compared across teams, but weights are the teams' own, and two teams choosing different winners from similar data is a good discussion, not an error. If only one station is available, run session 2 as a rotation with other teams working on q4 to q9 at their tables. The listener version in the low-cost alternative measures detection directly and makes a good second test even when apps are available.