

Design Challenge: A Sealed Mini-World That Survives Twenty-One Days

Learning target: I can define criteria and constraints for a sealed model biosphere, use data from earlier prototypes to choose a design, plan the data my model will generate, and justify my decisions with energy and matter reasoning.

Transfer and design

About 55 min

Pairs

MS-ETS1-4 · practice

MS-ETS1-1 · practice

MS-ETS1-3 · practice

MS-LS2-3 · supports

engineering design

data analysis

writing

Name _____

Date _____

Period _____

Directions

Read the brief and the prototype report. Work through the four parts in order: define the problem precisely, learn from the three earlier prototypes, design your version and its test, then justify it. Every design choice must point to a criterion, a constraint or a prototype result. Numbers beat adjectives: 'enough plants' is not a design; 'eight sprigs of water plant, about 120 g' is.

You will need: This worksheet, Pencil and eraser, Calculator, Ruler for the sketch

The brief from the science club — For spring Science Night the club will display a sealed mini-world: a clear 20-liter tub, closed to matter, holding two pond snails, living plants, water and soil or gravel, sitting on the south-facing windowsill of Room 14. It must be sealed on day 0 and stay sealed for 21 days, with the snails and plants alive and healthy at the end. The club has \$25 to spend beyond the tub, no electricity may be used, nothing may be opened or added during the test, and the tub must not get hot enough to harm the animals. Sensors the club already owns read oxygen (%) and temperature (°C) through the lid.

Last year's club built three prototypes in the same tub on the same windowsill and tested each for 21 days. Their results are summarized below. All three were sealed to matter; sunlight entered through the clear walls.

Three prototype tests from last year (teaching dataset)

Simulated teaching dataset: the numbers are invented to be realistic, not measured.

Prototype	Soil or gravel	Plants	Water	Shade	Lowest oxygen (%) and day	Highest temperature (°C) and day	Snails alive on day 21	Other notes
P1	4 L garden soil	3 sprigs water plant (about 40 g)	6 L	none	16.8 on day 15	31 on day 9	0 (both died about day 16)	Soil darkened; carbon dioxide reading rose steadily
P2	2 L washed gravel	10 sprigs water plant (about 150 g)	8 L	none	20.6 on day 3	35 on day 11	0 (both died about day 12)	Water very warm by midday; plants pale after day 14
P3	1 L potting soil + 2 L gravel	8 sprigs water plant (about 120 g) and 2 small land plants	7 L	shade cloth over the sunny half	19.7 on day 18	28 on day 10	2	Heavy condensation on the walls from day 6; plants yellowing on day 19

Simulated results written for teaching. The patterns (oxygen falling with rich soil, temperature climbing in a sealed clear tub in direct sun, condensation blocking light) are realistic, but these numbers were not measured in a real classroom.

Materials the club can buy (prices are teaching estimates)

Item	Cost	Notes
Water plant sprigs (bundle of 5, about 75 g)	\$4	Produce oxygen in light; need light to reach them
Small land plant	\$3 each	Needs soil; adds oxygen in light
Potting soil, 1 L	\$1	Holds roots; contains decomposers
Washed gravel, 1 L	\$1	No decomposers; holds nothing for roots
Shade cloth, 1 m ²	\$5	Cuts sunlight on the covered part by about half
Reflective foil, 1 m ²	\$2	Reflects sunlight; blocks light where applied
Pond snails	free	Two provided by the club; need oxygen in the water and algae or plant matter to eat
Dechlorinated water	free	Any amount up to 12 L

Part A: Define the problem precisely

A criterion describes what success looks like and must be testable with a number or a clear yes/no check. A constraint is a limit the design must stay inside. 'The snails should be happy' is not testable; 'both snails alive and moving on day 21' is.

1. Write three criteria for a successful mini-world, each with the test that would show it was met. At least one must involve oxygen and one must involve temperature.

Criterion	How it will be tested (number or check)
Criterion 1	
Criterion 2	
Criterion 3	

2. List every constraint in the brief. Then add one constraint the brief does not state but that the science demands (think about what a sealed tub cannot do with the energy that enters it).

Part B: Learn from the prototypes

3. For each prototype, name the one feature most worth keeping and explain why the prototype still failed, using energy or matter in your reason.

Best feature worth keeping	Why it failed (use energy or matter in the reason)
P1	
P2	
P3	

4. P2 had the most plants and the highest oxygen, yet it reached 35 °C and its snails died first. Explain where the energy that heated P2 came from, how it got in, and why it could not get out as easily as it got in.

5. P1's oxygen fell to 16.8% while P2's never dropped below 20.6%. Name the difference between the two builds that explains this, and the living things responsible.

Part C: Your design and its test

6. Fill in your design. Amounts and costs are required. Total the cost at the bottom and check it against the \$25 limit.

Your choice (with amounts)	Cost	Which criterion, constraint or prototype result it answers
Soil or gravel		
Plants		
Water		
Light control (shade, foil, position)		
Anything else		

7. Sketch your tub on the windowsill, viewed from the side. Label the soil or gravel, water, plants, snails, and any shade or foil. Add arrows showing energy entering the tub (label the transfer method) and energy leaving it (label the method), and write 'matter: sealed' on the lid.



8. Plan the data your model will generate. State what you will measure, how often, and a **decision rule** for each criterion: a number that, if crossed before day 21, means the design has failed and must be modified (for example: 'if oxygen reads below ___ on any day, stop and change ___').

Part D: Justify and plan the next version

9. Justify your design in a paragraph. Explain how each major choice meets a criterion or constraint, which prototype result it is based on, and what trade-off you accepted (something you gave up to get something else). Use the words radiation, conduction, decomposers and closed to matter correctly.

10. Suppose your test reaches day 10 with oxygen at 19.2% and falling about 0.2 points per day. Predict the day-21 reading if nothing changes, decide whether a modification is needed, and state the **one** change you would make for version 2. Explain why engineers change one thing at a time.

Borrow the best, fix the worst

If designing from scratch feels like too much, start from P3, the only prototype whose snails survived, and ask three questions: What went wrong in P3 (condensation blocking light, plants yellowing)? Which P2 feature would fix that (more plants, but P2 also overheated)? Which P1 result warns you about adding soil (decomposers using oxygen)? A design that keeps P3's shade, uses a little less soil than P3, adds a few more water plants, and moves the tub slightly back from the glass is a reasonable starting point; your job is to say how much and why.

Scale it up to Biosphere 2

The real Biosphere 2 in Arizona enclosed about 1.3 hectares of land under glass and sealed in eight people for two years. Its oxygen fell from about 21% to about 14% in roughly sixteen months, and the cause turned out to be soil microbes. Compare your mini-world's decision rules with what Biosphere 2's designers would have needed: what measurements, what thresholds, and what modifications are possible when you cannot open the lid for two years? Write a short memo (one page) advising the designers on one change you would have made before sealing the doors, based on your prototype analysis.