

Two Creams, One Choice: Confirm the New Substance, Then Judge the Design

Learning target: I can confirm from property data that a reaction made a new substance, then evaluate competing designs against stated criteria and constraints using test results, choose one, and justify the choice including its trade-off.

Transfer and design

About 50 min

Pairs

MS-ETS1-2 · practice

MS-PS1-2 · practice

engineering design

data analysis

writing

Name _____

Date _____

Period _____

Directions

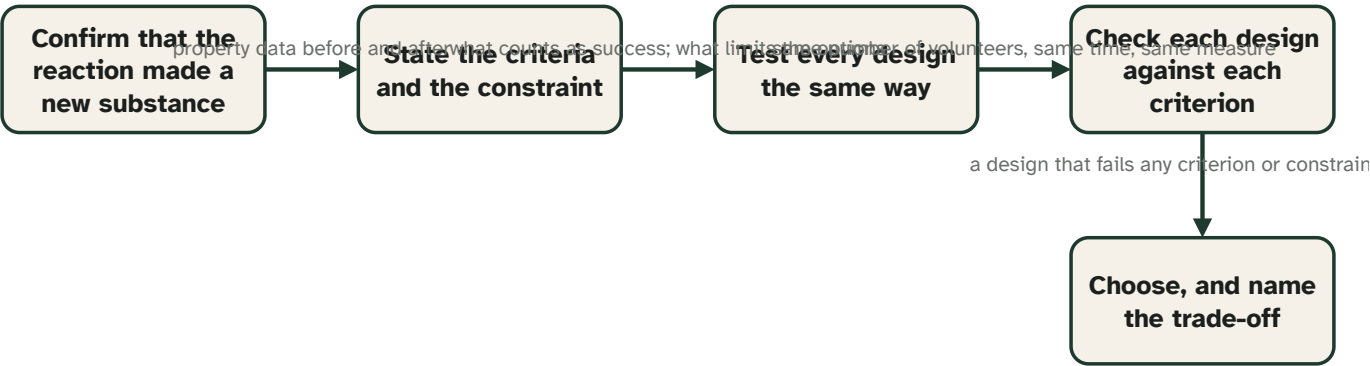
You are the review team at a small company. Read the brief, then work through the four parts in order: confirm that the chemist really made a new substance (Part A), evaluate the three cream designs against the criteria and constraint (Part B), make and justify a decision (Part C), and respond to a change in the constraint (Part D). Everything in this sheet is made up: the company, the compounds and the volunteers. Nothing here is advice about any real medicine.

You will need: This worksheet, Pencil, Calculator (optional)

The brief

Lantern Labs sells an anti-itch cream for insect bites. Its active ingredient, Compound R, is a powder taken from the leaves of a mint relative. Customers like the relief but complain that the cream stings for the first minute. The company's chemist ran a reaction on Compound R, hoping to make a new substance, Compound S, that keeps the relief and loses the sting. She handed the review team two sets of results: the property tests she ran on R and on S, and a volunteer trial of three cream designs. The team's job is to decide whether S is really a new substance and, if so, which cream the company should make.

Figure 1. The review team's process



The process is systematic on purpose: the same checks are applied to every design in the same order.

Part A: Is Compound S a new substance?

Table 1. Property tests on Compound R (before the reaction) and Compound S (after), teaching dataset

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

Property	Compound R (before)	Compound S (after)
Appearance	pale yellow powder	white powder
Melting range	121 to 122 °C	121 to 123 °C
Solubility in water at 25 °C (g per 100 mL)	1.8	6.4
Density (g/cm ³)	1.31	1.29
Odor	sharp, minty	none
Burns when held in a flame?	yes	yes

Simulated data for teaching. All tests on pure, dried powders at the same temperature. The density method is good to about ± 0.03 g/cm³; repeat solubility tests agree within 0.2 g per 100 mL.

1. Sort the six properties in Table 1 into two groups: those that clearly differ between R and S, and those that do not (either the same, or different by less than the method's uncertainty). Use the uncertainty statements in the caption.
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2. The melting ranges overlap. Does that mean R and S are the same substance? What does the narrowness of each range (about 1 to 2 °C) tell you about the two powders?

3. Calculate how many times more soluble S is than R at 25 °C. Then calculate the density difference and compare it with the $\pm 0.03 \text{ g/cm}^3$ uncertainty: is the density difference real? Show your work.

4. Should the review team accept that S is a different substance from R? Give your decision with the two strongest pieces of evidence, and name the one test the chemist could have skipped because it could not tell R from S.

Part B: Evaluate the three designs

- ☐ Criterion 1: At least 70% of volunteers report itch relief within 30 minutes.
- ☐ Criterion 2: No more than 10% of volunteers report stinging.
- ☐ Constraint: The cream must cost no more than \$4.00 per tube to make.

Table 2. Volunteer trial of three cream designs, teaching dataset

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

Design	Active ingredient and amount per tube	Volunteers with relief within 30 min (of 40)	Volunteers reporting stinging (of 40)	Cost to make per tube
Cream 1	Compound R, 2.0 g	33	14	\$2.60
Cream 2	Compound S, 2.0 g	30	2	\$3.90
Cream 3	Compound S, 1.0 g	23	1	\$3.10

Simulated data for teaching. Each cream was tested on 40 adult volunteers under the same conditions; each volunteer used one cream on one bite and reported at 30 minutes.

5. Complete the evaluation table. Convert each count to a percentage of 40 and write yes or no in each check column. Show one percentage calculation below the table.

Relief (%)	Meets Criterion 1 ($\geq 70\%$)?	Stinging (%)	Meets Criterion 2 ($\leq 10\%$)?	Meets cost constraint ($\leq \$4.00$)?
Cream 1 (R, 2.0 g)				
Cream 2 (S, 2.0 g)				
Cream 3 (S, 1.0 g)				

6. Which design or designs pass every criterion and the constraint? For each design that fails, name exactly what it fails.

7. A manager says, 'Cream 1 relieved the most people, so it is the best design.' Using Figure 1, explain why that is not how a systematic evaluation works.

Part C: Decide and justify

8. Write the review team's recommendation in a paragraph. It must (a) name the cream to make, (b) cite the percentages and cost that show it meets each criterion and the constraint, (c) name the trade-off the company accepts by choosing it over the design with the most relief, and (d) explain in one sentence how Part A's property evidence supports trusting that this cream contains a different substance from the old one.

Part D: The constraint changes

9. The company lowers the cost constraint to \$3.50 per tube. Which designs still pass? Propose a modified design that might pass everything, say what you would change and why, and name the one test you would run before recommending it.

10. Explain why the trial gave every cream the same number of volunteers, the same 30-minute limit and the same way of reporting. What would go wrong in the evaluation table if Cream 3 had been tested on 60 people for 45 minutes?

Percentages out of 40 and a pass/fail habit

To turn a count out of 40 into a percentage, divide by 40 and multiply by 100: $30 \div 40 \times 100 = 75\%$. A shortcut: each volunteer is 2.5%, so multiply the count by 2.5. For the check columns, write the rule next to the number before deciding: '75% $\geq$ 70%? yes.' For Part A, start by crossing out any property whose two values are identical or closer than the uncertainty in the caption; what is left is your evidence.

Design the next trial

Cream 2 passed, but 25% of volunteers got no relief within 30 minutes. Propose a fourth design (for example, a different amount of Compound S, or S mixed with a small amount of R) and predict its three results in Table 2's format, with a reason for each prediction based on Creams 1 to 3. Then write the one new criterion you would add to the company's list, explain why the current three criteria let a cream that smells bad or separates in the tube pass, and describe how you would measure your new criterion fairly.