

Quick start · Kit 6

Target: evaluate all criteria and constraints, justify a tradeoff, propose a design and test, then revise against staged evidence. Grade 6 provisional; NGSS 6–8 band. Prerequisites: table headings, °C, time, temperature change, comparable trials and claim scope; teach P when needed. Materials: paper and pencil; optional calculator, projection, pointing, oral responses or labeled responses.

Print and sequence

Print Kit6-v1.0.0-Teach-the-Design-Challenge.pdf (P/M/G/I0/I1); hand out I0 before I1. Model M, guide G, collect I independently, reveal fictional prototypes, then revise. Quick Check repeats I0/I1; use it only before exposure. The full packet preview is not a class handout that preserves the staged reveal.

Other selections: Kit6-v1.0.0-Use-a-Quick-Check.pdf; Reteach-Meet-Every-Requirement.pdf; Reteach-Improve-the-Design-and-the-Test.pdf; Use-a-Later-Check.pdf. All are in print-selections. Exact page and task references are in X; teacher sections P/M/G/I/A/B/T support matching selections.

Notice → next supplied task

Missing a constraint or the rule for all trials → A, then fresh Ac. Unsupported improvement or a confounded feature claim → B, then fresh Bc. Unclear writing → clarify aloud first. After I, use still unseen T, not Quick Check. Record response mode, support and actual exposure; do not assign a score or mastery label.

Author estimates, not classroom timings: preparation 12–18 min; full route 55–70 min or two sessions (break after G); reteach 12–18 min; later check 10–15 min. No apparatus is required. Practical P1 is separate; paper analysis does not demonstrate physical construction or testing. Constructed data labels travel with every table.

P · Teach the bridge

Say: “A criterion tells us what performance must do; constraints tell us what resources and size we may use. I check each separately. A prediction says what might happen in a future test; supplied results concern a specified completed fictional record.”

K6-D-P · Supplied design record

Constructed teaching data: these values were invented for this activity, not collected in an experiment.

Design	Tokens	Added mm	Trial 1 final °C	Trial 2 final °C	Trial 3 final °C
H	3	12	16	16	16

K6-P1 · Criterion: final $\leq 16^{\circ}\text{C}$ in every 15-minute trial; constraints ≤ 4 tokens and ≤ 15 mm. H: 16/16/16°C, 3 tokens, 12 mm; all pass nominally, at the temperature boundary.

K6-P2 · It warms 6°C; it neither cools nor stops transfer. Sealing a gap is an untested prediction. Compare fresh matched samples with unchanged H, using the same mass, start, room, time, cups, lids and procedure, with repeated trials. A fair comparison of whole designs is enough for the complete modified design; it does not uniquely isolate a mechanism.

Trace 10 → 16°C on a number line if the direction is unclear. Ask which conditions must match; if the learner can only name a winner, ask for a check of all requirements. If the learner needs more measurement practice, use the preserved Kit 1 measurement reteach; P itself provides the necessary bridge now. Respond in connected prose, orally while pointing to data, or with a labeled representation. Clarify the question, table access, vocabulary and response mode before choosing a reteach. Sparse language can express adequate reasoning.

M · Think aloud and constraint checks

Worked from K6-D-M (student p. 2): 100 g water starts at 10°C in a 22°C room; 20 minutes; fresh matched trials and passive conditions as stated in the model. Each requirement is checked separately.

Completed constraint-check table · K6-D-M

Teacher calculations from constructed teaching data, not experimental measurements.

Design	Every trial $\leq 15.5^{\circ}\text{C}$	Tokens ≤ 8	Added ≤ 20 mm	Feasible?
A	15 / 15.5 / 15: PASS	5: PASS	18 mm: PASS	Yes
B	14 / 14.5 / 14: PASS	8: PASS	20 mm: PASS	Yes
C	13.5 / 14 / 13.5: PASS	9: FAIL	18 mm: PASS	No
D	14.5 / 15 / 14.5: PASS	6: PASS	24 mm: FAIL	No

Say: “First, temperatures: all must be at most 15.5°C , not just one or the mean. Next, tokens: at most 8; then added thickness: at most 20 mm. A: pass/pass/pass; B: pass/pass/pass; C: pass/fail/pass; D: pass/pass/fail. I retain the raw records for C and D but do not call them feasible. A conserves resources; B has lower recorded warming. The brief does not declare one priority, so I explain mine.”

K6-M1 · A and B are feasible. A has temperatures of 15/15.5/15°C, uses 5 tokens and adds 18 mm; B has 14/14.5/14°C, uses 8 tokens and adds 20 mm. C violates the token limit: $9 > 8$ tokens; D violates the thickness limit: $24 > 20$ mm. All temperature changes are positive: A 5/5.5/5°C, B 4/4.5/4°C, C 3.5/4/3.5°C, D 4.5/5/4.5°C.

K6-M2 · A has a defensible priority: conserve 3 tokens and 2 mm while satisfying the supplied brief. B has a defensible priority: smaller warming in all three pairs, with final readings 1°C below A, using the full budget and size allowance. Both choices are accepted; neither is universally best. At a displayed boundary, accuracy and limited trials are relevant; numerical headroom is not a reliability probability.

Limits: the room is warmer than the water, so net transfer is inward; cold is not escaping. Both A and B warm; neither cools nor stops transfer. Compare whole constructions; do not infer material properties or a specific pathway. Threshold headroom describes numbers, not accuracy or robustness. No real material or product performance is established.

G · Prompts and teaching moves

K6-D-G · Supplied design record

Constructed teaching data: these values were invented for this activity, not collected in an experiment.

Design	Tokens	Added mm	Trial 1 final °C	Trial 2 final °C	Trial 3 final °C
E	4	12	16	16.5	16
F	6	18	15	15.5	15
G	5	15	16	17.5	16

Ask: “Which exact trial could rule out an otherwise promising design?” Anticipated response: G passes on its mean. Move: point to “EVERY” and 17.5°C. Ask: “What do we give up choosing F? When would E be reasonable?” Anticipated response: the lowest temperature is automatically best. Move: compare 2 tokens and 6 mm with the 1°C difference, and require a priority.

K6-G1 · E and F are feasible. G fails: 17.5>17°C in trial 2, even though its mean of 16.5°C is under 17°C. Checking an average cannot replace the criterion for every trial.

K6-G2 · E saves 2 tokens and 6 mm; F ends 1°C below E in every pair (e.g., 16 vs 15°C and 16.5 vs 15.5°C). Either priority is justified. The room at 24°C is warmer than the water at 12°C, so net thermal energy transfers toward the water. Less warming of matched mass is consistent with less net energy entering over the interval, without proving a unique pathway.

Say: “The room is warmer; the thermal energy account explains warming. The table supports recorded performance, not unique proof of conduction.” Accept oral or labeled answers; do not demand a fixed paragraph. Avoid requiring means.

I · Independent and redesign keys

Collect I0 before I1. The teacher does not model I. The I1 record concerns specified fictional prototypes only. Quick Check reuses the exact I task; it is not fresh after the lesson.

K6-I1 · J and K are feasible. L fails: $17 > 16.5^{\circ}\text{C}$ in trial 2; N exceeds the token limit: $6 > 5$ tokens. J uses 3 tokens and adds 14 mm versus K at 5 tokens and 19 mm; K endpoints are $1/0.5/1.5^{\circ}\text{C}$ below J. Both choices are accepted with a stated priority and bounded claim. Changes: J $5/5/5.5^{\circ}\text{C}$; K $4/4.5/4^{\circ}\text{C}$; L $4/6/4^{\circ}\text{C}$; N $3/3.5/3^{\circ}\text{C}$.

K6-I2 · Accept a specified seam, wrap or geometry change satisfying ≤ 5 tokens and ≤ 19 mm, with a reason and prediction. Actual success remains unknown. Test the modified design against the unchanged choice, using fresh 80 g samples starting at 11°C in a 23°C room for 16 min, with matched cups, lids, exposure and readout; use ≥ 3 paired fresh trials for instructional comparison, not a statistical guarantee. Retain raw starts, endpoints, room temperatures, times and departures from the procedure. Any repeated larger warming or criterion miss would challenge success; close values may remain uncertain.

K6-I3 · J-sealed misses the criterion: $17 > 16.5^{\circ}\text{C}$ in trial 3. It is not a feasible improvement, even though trials 1 and 2 are equal to or lower than J. K-thin passes all requirements: $15.5/16/16^{\circ}\text{C}$, 5 tokens, 17 mm. It reduces thickness by 2 mm but warms more than K by $0.5/0.5/1^{\circ}\text{C}$. Accept K-thin for smaller size and a nominal pass, original K for lower recorded warming, or J for saving resources. There is no universal or reliable superiority or attribution to a unique pathway. The redesign record is separately constructed, not an empirical test of the student proposal.

K6-I4 · Keep an explicit hypothesis with scope, or revise a choice using the tradeoff. An actual matched repeated test with known construction, accuracy and conditions is needed to claim real performance; room, duration and mass variations require new tests. Unsupported conclusions include: always succeeds, stops transfer, proves the exact mechanism, or guarantees the student proposal.

I can elicit feasibility, tradeoff, a proposal, reassessment and a bounded explanation; it cannot establish mastery, real construction or testing, or actual design performance. Accept different modifications with correct constraints and a matched test; do not grade against one preferred prototype.

A/Ac · Meet every requirement

K6-D-A · Supplied design record

Constructed teaching data: these values were invented for this activity, not collected in an experiment.

Design	Tokens	Added mm	Trial 1 final °C	Trial 2 final °C	Trial 3 final °C
P	7	14	13	13.5	13
Q	5	21	14	14	14.5
R	4	18	14	16	14
S	5	18	14.5	15	14.5

Intervention: make three columns: performance / tokens / thickness. Say: “I keep the attractive number but it cannot erase another requirement. I check every trial before deciding.” The learner checks P, then R; model S without inventing a margin.

K6-A1 · Only S is feasible. P exceeds the budget: 7>5 tokens, despite having the lowest readings. Q exceeds the thickness limit: 21>18 mm. R has trial 2=16>15°C; its mean of 14.67°C is irrelevant to the rule for all trials. S has 14.5/15/14.5°C, 5 tokens and 18 mm, so it passes nominally.

K6-A2 · Recommend S for these records: 20 min, 100 g, a 10°C start and a 22°C room. Trial 2 is exactly 15°C: a 0°C displayed margin. Accuracy and future variability are unknown; seek a matched repeat with a characterized instrument and procedure, and potentially a modified design, retaining raw readings. Margin alone is no reliability estimate.

Withhold Ac until practice ends. Fresh Ac changes the budget and has an empty feasible set; the complete key follows.

K6-A3 · None is feasible. U exceeds the budget: 5>4 tokens; V exceeds the thickness limit: 19>18 mm; W has trial 2=16>15°C. Propose a change within the existing limits and then test it, or explicitly request a revised brief. Do not silently relax limits, average away failure or fabricate results.

If the learner insists on a winner, ask whether any row passes all three checks. If arithmetic is right but language is unclear, ask for an explanation through pointing or speech. Ac is fresh only until shown.

B/Bc · Improve the design and the test

K6-D-B · Supplied design record

Constructed teaching data: these values were invented for this activity, not collected in an experiment.

Setup	Water g	Start °C	After 15 min °C
Old whole design	100	10	16
New whole design	200	12	15

Say: “The new water has a different mass and start. I can calculate changes, but that does not remove confounds. I need a comparison matched to my question. A comparison of whole designs may vary multiple construction features; a claim about the seam alone cannot.”

K6-B1 · Old: +6°C; new: +3°C. Describe these complete setups only. Water masses of 100 vs 200 g and starts of 10 vs 12°C differ: neither the lower endpoint nor the smaller change isolates a sleeve improvement.

K6-B2 · Match water mass, start, room, time, cups, lids, exposure and readout across fresh paired repeats; compare the unchanged old design with the new design. For seam causation, hold layer count and other construction features fixed while varying the seam. Keep raw readings; mark missing readings and record documented departures from the procedure. Repeat a compromised trial without erasing it.

K6-B3 · The new whole design shows 2°C less warming than the old design in each pair: old changes 6/5/6°C, new changes 4/3/4°C. This supports a cautious preference for the new whole design under these conditions. Both seam and layers changed, so a claim that the seam alone caused the difference is unsupported. An additional paired comparison with layer count fixed and only the seam varied, with repeats and accuracy checks, supports the narrower question. Performance is not guaranteed.

Have the learner draw matched old and new setups with labels for mass, start, time and room temperature. Withhold Bc until practice ends. Bc matches test conditions but varies the seam and layers: an accepted conclusion about the whole design must not be confused with isolated feature causation. Unexpected raw readings remain visible.

T · Transfer and revision

K6-T1 · Originally, X and Y both pass nominally. Under a 4-token budget, only X is feasible at 22°C; Y exceeds the budget: 6>4 tokens. Scope: 100 g, a 10°C start, 20 min, a 22°C room and the supplied construction; no guarantee elsewhere.

K6-T2 · X has 17/17.5/17°C, all three >15°C: it does not pass at 28°C. Keep the 22°C conclusion and narrow any generalization. The room changed from 22 → 28°C; there is no Y record at 28°C, so X cannot be ranked against Y there. X warms 7/7.5/7°C in the new record.

K6-T3 · Accept a specified prototype within 4 tokens and 18 mm with a rationale, or a matched X/Y test at 28°C (Y is still over budget but can inform design features). Check matched mass, start, time and procedure, known accuracy, and fresh trials. Close or variable values may prevent a confident preference; they do not prove equivalence. An unmet brief is a valid outcome; do not promise improvement.

Give T0, then T1. A response may retain earlier bounded feasibility while concluding that the new record fails the performance criterion. There are no data for Y in the warmer room, so there is no ranking there. A coherent answer elicits revision under changed resources and environment; it does not establish mastery or equivalent forms. A redesign hypothesis need not be successful.

Science and specific standards

Temperature is not total energy; type, state and amount matter. Doubling Celsius does not double energy. In these passive covered-water cases, net thermal energy transfers from the warmer room toward the cooler water. Less warming of matched mass over a matched interval is consistent with less net energy entering the water; endpoints do not give instantaneous rates or identify conduction, convection and radiation separately.

Official NGSS MS-PS3-3 supports transfer direction and the distinction between temperature and energy; K6-P/G/I invoke selected concepts and design ideas, but paper analysis does not complete designing, constructing and testing a device. MS-ETS1-3 informs systematic criteria and constraints and the analysis of design data (M/G/I/A); paper proposals do not demonstrate an empirical combination of features. MS-ETS1-4 informs proposed iterative model and test thinking (I/B), not completed physical tests or generation of model data.

Verified 2026-09-30 official sources: <https://www.nextgenscience.org/pe/ms-ps3-3-energy> ; <https://www.nextgenscience.org/pe/ms-ets1-3-engineering-design> ; <https://www.nextgenscience.org/pe/ms-ets1-4-engineering-design> . Original paraphrases and data; no reproduced third-party lesson or diagram, or endorsement. Current site Terms of Use apply; no new external rights are granted.

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Print, page and exposure map

Full student pages: P=1, M=2, G=3, I0=4, I1=5, A=6, Ac=7, B=8, Bc=9, T0=10, T1=11. Teach selection pp. 1–5=P/M/G/I0/I1; guide P–I pp. 2–5. Quick selection pp. 1–2=I0/I1; guide I p. 5. Meet Every Requirement selection pp. 1–2=A/Ac; guide A p. 6. Improve Design and Test selection pp. 1–2=B/Bc; guide B p. 7. Later selection pp. 1–2=T0/T1; guide T p. 8.

Stable IDs: K6-P1/P2 bridge; K6-M1/M2 modeled; K6-G1/G2 practiced; K6-I1–I4 independent, then staged revision, reused in Quick Check; K6-A1/A2 and B1/B2 interventions; K6-A3/B3 fresh rechecks; K6-T1–T3 fresh later tasks until shown. Datasets have the K6-D- prefix, separate from task IDs. No numerical record reuses earlier kits. The original category design challenge informed the structure; this kit uses new values and relationships.

Preserve the I0 → I1 and T0 → T1 reveal order: print on one side and distribute separately. The full packet HTML/PDF preview contains both and does not preserve the staged reveal. If checks are already exposed, use them for practice and record the limitation; do not claim freshness. Respond in connected prose, orally while pointing to data, or with a labeled representation. Clarify the question, table access, vocabulary and response mode before choosing a reteach. Sparse language can express adequate reasoning.

Generated print references

Teach-the-Design-Challenge: selection p1 = full p1 (P; K6-P1/K6-P2), selection p2 = full p2 (M; K6-M1/K6-M2), selection p3 = full p3 (G; K6-G1/K6-G2), selection p4 = full p4 (I0; K6-I1/K6-I2), selection p5 = full p5 (I1; K6-I3/K6-I4)

Use-a-Quick-Check: selection p1 = full p4 (I0; K6-I1/K6-I2), selection p2 = full p5 (I1; K6-I3/K6-I4)

Reteach-Meet-Every-Requirement: selection p1 = full p6 (A; K6-A1/K6-A2), selection p2 = full p7 (Ac; K6-A3)

Teacher answers: locate the identical task ID under its matching key heading. These page references describe this version only; do not mix versions.

Generated print references

Reteach-Improve-the-Design-and-the-Test: selection p1 = full p8 (B; K6-B1/K6-B2), selection p2 = full p9 (Bc; K6-B3)

Use-a-Later-Check: selection p1 = full p10 (T0; K6-T1), selection p2 = full p11 (T1; K6-T2/K6-T3)

Teacher answers: locate the identical task ID under its matching key heading. These page references describe this version only; do not mix versions.