

Save the Ice Cube: Design, Test and Improve an Insulated Holder

Investigation question: How can you use everyday materials to slow the energy flowing from a warm room into an ice cube, so that as little of it as possible melts in 25 minutes?

Engineering design challenge

Groups of 4

2 sessions

Setup 5 · Activity 95 · Cleanup 10 min

MS-ETS1-3 · assesses

MS-PS3-3 · practice

MS-ETS1-1 · practice

MS-PS1-4 · supports

Scientific purpose

Students restate a design brief as measurable criteria and constraints, then design and build an insulated holder from a budgeted menu of everyday materials and test it against a bare control by weighing how much of a 15 g ice puck melts in 25 minutes. After the class posts its first-round data, groups identify the features shared by the best designs, combine them into a second version, retest it, and explain with particles why trapped still air and fewer contact paths slow the energy flowing into the ice.

Why this helps students with this chapter

Students often believe a blanket or a sweater 'makes heat', so wrapping ice in fleece seems like a way to melt it. Building a holder and weighing the ice that survives turns that belief into a testable prediction, and the bare control makes every result comparable. Pooling class data shows that the winning designs share features, mostly thick layers of trapped still air all the way around, including underneath, which is the evidence-based redesign that engineering asks for. Weighing a 15 g puck before and after turns an invisible energy flow into a number students can trust.

Standards connections

MS-ETS1-3 (assesses, analyzing test data from several designs to identify the best characteristics and combine them into a new solution): Groups compare the class's first-round results, name the features shared by the most and least effective holders (q5), build a second version that combines features from at least two other designs, and retest it (q6, q7). The class table and the written redesign rationale are direct evidence for this PE.

MS-PS3-3 (practice, applying scientific principles to design, construct and test a device that minimizes thermal energy transfer): This is a California Grade 6 PE, revisited here in a Grade 7 lesson on state changes. Students design, build and test an insulated holder and explain its performance with energy transfer and particles. No one calculates the energy transferred, consistent with the assessment boundary.

MS-ETS1-1 (practice, stating criteria and constraints precisely, including an impact on the environment): Students turn the brief into measurable targets (q1) and consider how a waste constraint would change the winning design (q11). The criteria are supplied, so this is practice rather than full evidence for the PE.

MS-PS1-4 (supports, melting as a state change driven by energy added from warmer surroundings): The lab rests on the chapter's model: the ice melts because energy flows into it from the warmer room, and it melts at 0 °C whatever the insulation (q10). Students use the model rather than develop it here.

Roles (rotate each session)

- **Project manager:** Keeps the group on the clock and inside the 10-point budget, checks the design against every criterion and constraint, and gets the teacher's initials before building.
- **Builder:** Leads construction, makes sure the holder fits the size box and can be opened and closed in under 30 seconds.
- **Tester:** Tares the scale, weighs each puck at the start and end, runs the 25-minute timer, and pours off meltwater the same way every time.
- **Data analyst:** Computes mass lost and percent lost for the design and the control, posts results on the class chart, and leads the comparison of class data.

Materials

Item	Quantity	Per	Note
Ice pucks: 15 g (15 mL) of tap water frozen overnight in 1-oz (30 mL) portion cups	4 (two tests and two controls)	group	Make about 10 spares for the class.
3-oz (about 90 mL) clear plastic cups to hold the puck during each test	4	group	
Pocket digital scale reading to 0.1 g	1 per 2 groups	class	A kitchen scale reading to 1 g works but makes differences hard to see.
Material menu supply: aluminum foil, newspaper, paper towels, plastic wrap, cotton balls, felt or fleece squares, bubble wrap, packing peanuts, small cardboard boxes or paper cups, 8- to 12-oz foam cups with lids	enough for each group to spend 10 points per round	class	Packing materials and newspaper can be collected from deliveries and recycling.
Masking tape (about 1 m), rubber bands, scissors and a ruler	1 set	group	
Size-check box, 12 cm × 12 cm × 12 cm inside	1	class	
Plastic spoon, paper towels and a waste cup for meltwater	1 spoon, a few towels, 1 cup	group	
Timer and a room thermometer	1 timer per group; 1 thermometer	group	One room thermometer for the class is enough.

Estimated cost: About 10 to 20 per class with scales on hand; about 40 to 70 if pocket scales must be bought (an estimate; Estimate: portion cups and 3-oz cups about \$3 per 100 each, cotton balls about \$2, felt squares about \$0.30 each, a roll of foil about \$3, foam cups about \$3 per sleeve; newspaper, bubble wrap and packing peanuts are free from recycling. Pocket scales reading 0.1 g cost about \$10 to \$15 each, one per two groups.)

Safety

- Scissors can cut: cut away from your body and hand scissors over handle first. Foil edges can also cut fingers.
- Freezer-cold ice can stick to skin. Move the puck with its portion cup or a spoon, not with bare fingers for long.
- Water on the floor is a slip hazard and water on a scale can ruin it. Pour meltwater only into the waste cup over a paper towel.
- Do not eat any material: some packing peanuts are made of cornstarch and look like snacks but are not food.
- No heat sources, salt, extra ice, cold packs or refrigerators: they break the constraints and some, such as salt on ice, can make surfaces cold enough to injure skin.

Teacher preparation and setup

1. The day before, pour 15.0 g (15 mL) of tap water into each portion cup, set them on a tray and freeze them for at least 12 hours. Keep them in the freezer until the moment each test starts.
2. Collect the menu materials and post the price list: foil 30 × 30 cm, 1 point; newspaper 2 sheets, 1 point; paper towels 3 sheets, 1 point; plastic wrap 30 cm, 1 point; cotton balls 15, 2 points; felt or fleece 20 × 20 cm, 2 points; bubble wrap 20 × 30 cm, 2 points; packing peanuts 1 cup, 2 points; small box or paper cup, 2 points; foam cup with lid, 4 points; tape and rubber bands free.
3. Pick one test area away from windows, sunlight, heaters and air vents, and plan to record the room temperature at the start of each round. Every group tests in the same area.
4. Check each pocket scale with a known mass (a U.S. nickel is 5.0 g) and replace weak batteries.
5. If possible, run one bare control in your room beforehand to learn how much of a puck melts in 25 minutes (roughly 10 to 25 percent is a reasonable guess, but it has not been tested), and lengthen the test if your room is cool.

Investigation design

Independent variable	The holder design: which materials are used, how thick they are, and how they are arranged around the puck.
Dependent variable	The percent of the ice puck's starting mass that melted in 25 minutes.
Controlled	Ice pucks of 15 g made the same way and taken from the same freezer; Test time of 25 minutes for every design and control; The same test area and the same 3-oz cup type; The same pouring method, without blotting; The same scale for the start and end masses of each puck
Trials	One test per design per round, each with its own bare control run at the same time; the class pools all controls so every round has a reliable control median.
Comparison	Each design against the bare control of the same round, version 2 against version 1, and features of the best and weakest designs across the class.

Student procedure

1. Session 1. Read the design brief. As a group, rewrite each criterion and constraint as a measurable target (q1). The project manager posts them where everyone can see.
2. Each member sketches one idea for three minutes. The group chooses or combines ideas, draws version 1 with labeled materials and arrows showing where energy could enter the ice (drawing), and adds up the cost. Get the teacher's initials before taking materials.
3. Build version 1 in 12 minutes. Check that it fits the size box and that the puck's cup can be taken out and put back within 30 seconds.
4. Start test 1. The tester sets an empty 3-oz cup on the scale, tares it, pops a puck from its portion cup into the 3-oz cup and records the start mass. The cup goes into the holder and the holder is closed. At the same time a second puck is weighed into a bare 3-oz cup and set uncovered beside it as the control. Start the 25-minute timer and record the room temperature.
5. While you wait, do not open the holder. Answer q2 and write a prediction of your design's percent lost.
6. At 25 minutes, take out the design's cup and the control. For each, hold the puck back with the spoon and tip the cup over the waste cup for five seconds to pour off the meltwater, without blotting. Weigh the cup and puck again (the scale is still tared for an empty cup) and record the end mass. Calculate mass lost and percent lost for both (q3).
7. Session 2. Post your round 1 results on the class chart: main features, cost, your design's percent lost and your control's percent lost. Answer q4 and, as a class, rank the designs by how their percent lost compared with their own control.
8. Study the class chart and answer q5: which features do the best three designs share, and what do the weakest three have in common? Then plan version 2, combining features from at least two other groups' designs, within the 10-point budget (q6). Modify or rebuild in 12 minutes.
9. Run test 2 exactly as test 1, with a new puck and a new bare control. While you wait, answer q8 to q11.
10. Weigh, calculate and post your round 2 results. Compare version 2 with version 1 (q7). Return reusable materials to the supply bins and put trash in the right bins.

Expected observations

- In a room near 22 °C, a bare control puck loses roughly 10 to 25 percent of its mass in 25 minutes (about 1.5 to 4 g); a cooler room or a longer test changes this, so compare each design with its own round's control.
- Well-insulated holders, with the cup surrounded on all sides by a few centimeters of cotton, packing peanuts, fleece or bubble wrap inside a closed shell, typically lose a third or less of the control's percent.
- Designs that wrap only the sides, leaving the cup sitting directly on the table or uncovered on top, do noticeably worse than fully enclosed designs of the same materials.
- Version 2 usually improves on version 1 when groups copy the enclosing and thickness features of the best designs; gains are smaller for groups whose version 1 was already good.

Likely difficulties

- Groups insulate the sides and forget the bottom and top. The side-view drawing with energy arrows is meant to catch this before building.
- Students open the holder to peek, letting room air in. Remind them that opening is part of criterion 2 only at the end of the test.
- Pouring off meltwater inconsistently (shaking, blotting) changes the end mass by a few tenths of a gram. Insist on the same five-second tip for every puck.
- Pucks differ by a few tenths of a gram. Percent lost corrects for this; check that analysts divide by each puck's own start mass.
- Groups start their tests at different times, so room conditions differ. Each design's own control handles this; compare ratios, not raw percents, across groups.

Structured debrief

1. Put the class chart on the board sorted by design percent lost divided by control percent lost. Ask what the top designs share. Typical answers: material on every side, including underneath and on top; a thick layer of fluffy or bubbly material; a closed outer shell; few gaps. Name the principle: still, trapped air carries energy poorly, and every gap lets moving room air carry energy in.
2. Ask which designs surprised the class. Fleece and cotton usually beat expectations; foil wrapped tightly against the cup with no air space often disappoints. Explain why: foil reflects much of the infrared energy the warm room radiates toward the ice, but a tight metal wrap also conducts energy readily wherever it touches, so foil works best as an outer layer around trapped air.
3. Return to the misconception: a blanket does not make heat. The same holder would keep a cup of hot cocoa warm longer, because it slows energy flowing in either direction. Ask students for one product that uses this (a lunch box, a thermos, a picnic cooler, a house's attic insulation).
4. Connect to the chapter: insulation changed how fast energy reached the ice, not the temperature at which it melted. Every puck that was melting sat at 0 °C. Ask: where did the energy that melted the control puck come from? From the warmer room air, the table and the infrared radiation of the room's surfaces.
5. Close on q11: many California cities restrict foam food containers. Ask how a recyclability constraint would push designs toward paper, cardboard, fabric and trapped air, and whether those could still meet the criteria.

Recording sheet: what students fill in

Lab 3 recording sheet: Save the ice cube

Design brief. A food-truck owner needs a cheap holder that keeps ice from melting while a customer waits. Your holder must keep a 15 g ice puck from melting for as long as possible at room temperature. **Criteria:** (1) in 25 minutes the puck loses less than one third of the percent that a bare puck loses in the same round; (2) the puck can be taken out and put back within 30 seconds. **Constraints:** a budget of 10 points from the menu; the holder fits inside a 12 cm cube; the puck stays in the 3-oz cup; no added cold (no extra ice, salt, cold packs or refrigerator) and no electricity; 12 minutes to build.

Material menu

Material	Amount	Cost (points)
Aluminum foil	30 cm × 30 cm	1
Newspaper	2 sheets	1
Paper towels	3 sheets	1
Plastic wrap	30 cm	1
Cotton balls	15	2
Felt or fleece	20 cm × 20 cm	2
Bubble wrap	20 cm × 30 cm	2
Packing peanuts	1 cup	2
Small cardboard box or paper cup	1	2
Foam cup with lid	1	4
Masking tape, rubber bands	as needed	0

1. Rewrite each criterion and constraint as a target you could check with a measurement or a yes/no test. Which one will be hardest to meet, and why?

Answer: Example: Criterion 1: percent lost by our puck in 25 minutes is less than (control's percent lost ÷ 3), checked with the scale. Criterion 2: the puck's cup comes out and goes back in under 30 seconds, checked with a timer. Constraints: total cost 10 points or less (add the menu prices); the holder fits in the 12 cm size box (yes/no); the puck stays in the 3-oz cup (yes/no); no extra ice, salt, cold packs, refrigerator or electricity (yes/no); built in 12 minutes (timer). The hardest is usually criterion 1, because criterion 2 pushes toward an easy-to-open holder with fewer layers, so the two criteria trade off.

Why: MS-ETS1-1 practice: each target must be checkable. Any well-reasoned choice of hardest criterion earns credit; the trade-off between access and insulation is the strongest answer.

- Each criterion and constraint restated so it can be checked by measurement or yes/no
- The percent target is tied to the control
- Names the hardest one with a reason

-  Sketch version 1 from the side, as if cut in half. Label every material and its thickness. Draw arrows showing every path by which energy from the room could reach the ice (through the sides, top and bottom), and circle the path you think your design blocks least well. Write the total cost.

Answer: A side cutaway with every material labeled and its thickness given; arrows into the ice through the sides, top and bottom (from room air, the table and the room's surfaces); one path circled as the weakest; a cost total of 10 points or less.

Why: The arrows force students to consider the bottom and top, the paths most often left open.

- Materials and thicknesses labeled
- Energy arrows through all sides including top and bottom
- Weakest path identified
- Cost shown and within budget

2. For each material in your design, write the scientific reason you chose it (for example, what it traps, blocks or reflects).

Answer: Example reasons: cotton balls, fleece, packing peanuts and bubble wrap trap pockets of still air, which carries energy poorly; a closed box or foam cup stops room air from flowing past the ice; foil reflects much of the infrared energy given off by the warm room; a cardboard base keeps the cup off the warmer table; plastic wrap seals gaps.

Why: Credit any accurate reason. Watch for 'fleece keeps it cold' (it slows energy flow; it adds no cold).

- A reason for each material used
- Reasons refer to trapping air, blocking air flow, reflecting radiation or reducing contact

Our test results

Test	Start mass (g)	End mass (g)	Mass lost (g)	Percent lost (%)
Round 1: our design				
Round 1: bare control				
Round 2: our design				
Round 2: bare control				

Class results, round 1

Group	Main features	Cost	Design % lost	Control % lost
1				
2				
3				
4				
5				
6				
7				
8				

Analysis questions: answer key

3. Show how you calculated the percent lost for your round 1 design and your round 1 control. (Example: a puck that starts at 15.0 g and ends at 13.8 g lost 1.2 g, and $1.2 \div 15.0 \times 100 = 8$ percent.)

Answer: Method: mass lost = start mass – end mass; percent lost = mass lost $\div$ start mass $\times 100$. Example: design 15.1 g $\rightarrow$ 14.4 g, lost 0.7 g, $0.7 \div 15.1 \times 100 = 4.6$ percent; control 15.2 g $\rightarrow$ 12.4 g, lost 2.8 g, $2.8 \div 15.2 \times 100 = 18.4$ percent.

Why: Values are group-specific; check the subtraction and that each puck is divided by its own start mass. Percent lost compares pucks of slightly different masses fairly.

- Correct subtraction for mass lost
- Divides by the puck's own start mass and multiplies by 100
- Both design and control calculated

4. Did version 1 meet criterion 1? Show the comparison with one third of your control's percent lost.

Answer: Example: one third of the control's 18.4 percent is about 6.1 percent. Our design lost 4.6 percent, which is less than 6.1 percent, so it met criterion 1. (A design that lost 8 percent would not meet it.)

Why: The comparison must use the same round's control. Group-specific; check the arithmetic.

- Computes one third of the control's percent
- Compares the design's percent with it
- States met or not met

5. Use the class chart. Which features did the three best designs share? What did the three weakest designs have in common, or lack? Name the groups you are comparing.

Answer: Typical findings: the best designs surround the cup on all sides, including underneath and on top, with a thick layer (2 cm or more) of a fluffy or bubbly material such as cotton, fleece, packing peanuts or bubble wrap, closed inside a shell (box, foam cup or foil); the weakest designs leave the bottom or top open, use a single thin layer, or wrap foil tightly against the cup with no air space. Answers must name specific groups and their numbers.

Why: This is the core ETS1-3 evidence. Credit any pattern that is actually supported by the class chart, with groups and values cited.

- At least two shared features of the best designs
- At least one shared weakness of the weakest designs
- Cites groups and percent values from the chart

6. Describe version 2. Which features did you combine, from which groups' designs, and why do you expect each one to help? Show that it stays within 10 points.

Answer: Example: 'We kept our foam-cup shell (4 points), added Group 3's layer of cotton balls on all sides (2 points) and Group 6's cardboard base under the cup (2 points), and wrapped the outside in foil like Group 2 (1 point): 9 points. The cotton and cardboard trap still air on every side, including the bottom, which was our weakest path; the foil reflects energy radiated by the room.'

Why: Full credit needs features borrowed from at least two other designs, each tied to evidence from the chart and to a scientific reason, within budget.

- Combines features from at least two other groups
- Each feature justified by class data
- Each feature justified by a scientific principle
- Cost total within 10 points

7. Compare version 2 with version 1, using each round's percent lost and its control. Did combining features help? If not, suggest a reason and a next change.

Answer: Group-specific. Example: 'Version 2 lost 2.9 percent against a control of 17.5 percent (one sixth of the control); version 1 lost 4.6 percent against 18.4 percent (one quarter). Combining features helped.' If it did not help, a reasonable explanation names a specific cause (a gap left when the holder was rebuilt, a puck with a crack, a longer wait before weighing) and a next change.

Why: Comparing each version with its own round's control accounts for changes in room conditions between days.

- Uses percent lost and the controls for both rounds
- Judges whether the redesign helped
- If not, a plausible reason and a next step

8. A student says, 'Wrapping the ice in a fleece scarf will make it melt faster, because fleece is warm.' Which response is correct?

Answer: B. Fleece makes no energy. It traps still air, which slows the energy flowing from the warmer room into the ice, so the ice melts more slowly.

Why: A treats fabric as an energy source. C treats cold as something that flows. D is wrong because non-metal materials such as fleece and foam strongly affect energy transfer; that is how most insulation works.

9. Use particles to explain why a thick layer of trapped, still air slows the energy reaching the ice better than open room air or direct contact with the table. Then explain why a layer of foil around the outside can also help.

Answer: Energy reaches the ice when particles of warmer matter collide with the cup and pass energy along. In a solid table, particles are packed tightly and pass energy along quickly; in open room air, the particles are far apart but the air keeps moving, so fresh warm air keeps arriving at the cup. In trapped, still air the particles are far apart, so collisions that pass energy along are few, and the air cannot circulate to bring new warm air in, so energy moves through it slowly. A thick layer means the energy has a long path. Foil on the outside reflects much of the infrared radiation that the room's warm surfaces give off toward the ice, which is another path energy takes, and it also blocks air flow.

Why: The particle explanation of conduction and the role of moving air (convection) are the key ideas; the term convection is welcome but not required. The radiation point earns credit if the student says foil reflects energy from the room.

- Energy passes by collisions from warmer to cooler matter
- Trapped air: particles far apart and not circulating, so transfer is slow
- Contrasts with the table (tight particles) or moving room air
- Foil reflects radiated energy or blocks air flow

10. Your best design slowed the melting. Did it change the temperature at which the ice melts? Explain what insulation changes and what it does not.

Answer: No. The ice still melts at 0°C , its melting point, no matter how it is insulated. Insulation changes how fast energy reaches the ice, and so how much melts in 25 minutes; it does not change the temperature at which the state change happens.

Why: Links the engineering result back to the chapter's state-change model.

- Melting point stays 0°C
- Insulation changes the rate of energy transfer, not the melting point

11. Foam cups and packing peanuts often perform well, but most cannot go in a curbside recycling bin. Write one new criterion or constraint that takes this impact into account, and predict how it would change the winning designs.

Answer: Example: 'New constraint: every material must be recyclable or compostable in our city's bins' (or 'cost points double for foam'). Designs would shift toward cardboard, paper, cotton and fabric layers that still trap air; foam cups and peanuts would disappear, and the best designs might lose a little performance or need thicker layers to stay competitive.

Why: MS-ETS1-1 asks students to consider impacts on people and the environment. Any checkable criterion or constraint with a reasonable prediction earns credit.

- States a checkable criterion or constraint about waste or recyclability
- Predicts a specific change in the materials of winning designs
- Mentions a possible trade-off in performance or cost

Individual evidence of learning

Each student submits their own copy of the design drawing, the group's test results, the class chart and individual answers to q1 through q11. The ETS1-3 evidence is q5, q6 and q7: the student must use class data to name the best characteristics, combine them from other designs, and judge the result. The energy-transfer explanation is q9 and q10.

Assessment criteria

Criterion	Proficient looks like
Criteria and constraints	Every criterion and constraint is restated as a checkable target (percent lost below one third of the control, access under 30 seconds, 10 points or less, fits the 12 cm box, no added cold), and the hardest one is identified with a reason (q1).
Data and calculation	Start and end masses recorded to 0.1 g for design and control in both rounds, with mass lost and percent lost calculated correctly (q3, q4).
Analysis across designs	Names at least two features shared by the best designs and at least one shared weakness of the weakest, citing groups and numbers from the class chart (q5).
Combined redesign	Version 2 combines features from at least two other designs, each justified by class data and science, stays in budget, and is evaluated against version 1 using the controls (q6, q7).
Science explanation	Explains that energy flows from the warmer room into the ice, that trapped still air slows transfer because its particles are far apart and cannot circulate, that foil reflects radiated energy, and that insulation changes the rate of melting, not the 0 °C melting point (q8, q9, q10).

Accessibility adaptations

- Offer pre-cut material pieces and wide tape for students with limited fine-motor control; the builder role can direct while a partner cuts.
- Provide a percent-lost calculation frame ($\text{start} - \text{end} = \text{lost}$; $\text{lost} \div \text{start} \times 100 = \text{percent}$) and a calculator.

- Use a scale with a large display or one that speaks readings for students with low vision; the tester calls every value aloud.
- Accept a labeled photograph of the holder with spoken annotations instead of the cutaway drawing, as long as the energy paths are identified.

Low-cost alternative

Without 0.1 g scales, measure the meltwater instead: at the end of each test, pour the meltwater into a 10 mL graduated cylinder or a 10 mL oral syringe and read its volume (1 mL of water has a mass of about 1 g). Percent lost is the meltwater volume divided by 15 mL. With no measuring tools at all, rank designs by checking every five minutes which pucks still have sharp edges, though the comparison becomes qualitative.

Model limitations

This activity has not been physically tested by the authors; the expected percents are estimates, and melt amounts depend strongly on the room. A 15 g puck in a small cup is a model of a real problem such as a cooler or a food-truck ice bin: real containers are larger, are opened often and hold much more ice, so absolute results do not scale directly, but the ranking of insulating features usually does. Pouring off meltwater leaves a thin film on the puck, adding a small error to every end mass. The test does not separate the three ways energy reaches the ice (contact with the table and air, moving air, and infrared radiation), so students infer each material's role rather than measure it. Point costs are invented for the design problem and are not real prices.

Teacher notes

Rank class designs by their percent lost divided by their own control's percent lost, which removes most of the effect of room conditions. Expect controls of roughly 10 to 25 percent in 25 minutes in a room near 22 °C; this is an estimate, so run a control yourself first and lengthen the test if your room is cool. Do not ask students to calculate energy transferred; the MS-PS3-3 assessment boundary excludes it. Keep the class chart from round 1 posted for W7 (Jordan's wool-sock statement) and for the slide 25 synthesis.