

The Cookie Mine: Ore Grade, Costs and What Mining Leaves Behind

Investigation question: When does a deposit count as ore? Mine two cookies of different chip density with real costs for land, tools, time and cleanup, and find out which one makes a profit and what the land looks like afterward.

Physical model

Groups of 4

1 session

Setup 8 · Activity 35 · Cleanup 7 min

MS-ESS3-1 · practice

MS-ETS1-2 · practice

Scientific purpose

A chocolate-chip cookie stands in for a mineral deposit: the chips are the valuable mineral and the dough is the ordinary rock it is scattered through. Students prospect from the surface, estimate the grade, buy land, choose tools, mine against a timer, sell their chips, pay to restore the land and compute profit for a high-grade and a low-grade deposit. The lab makes concrete what 'ore' means (a concentration high enough to pay), shows that mining removes the resource from the map for good, and reveals why the same rock can be ore one year and not the next when prices change.

Why this helps students with this chapter

Students hear that copper ore is 'rock with enough copper to mine' but have no feel for what enough means or why a deposit stops being worth mining. Counting chips, paying for every square of land and every minute, and then trying to put the cookie back together turns ore grade, extraction cost and reclamation into numbers they computed and a mess they made. The low-grade cookie that loses money is the moment the idea of a cutoff grade lands.

Standards connections

MS-ESS3-1 (practice, the emphasis on limited, nonrenewable mineral resources and on distribution changing through human removal): The model shows that a mineral resource is a concentration worth extracting, that extraction empties the deposit, and that the land is changed; it builds the human-removal half of the explanation but does not itself explain the geologic processes that made the concentration, which Lab 1 does.

MS-ETS1-2 (practice, comparing options against criteria (profit) and constraints (time, budget, cleanup)): Students choose tools and mining time under cost constraints and judge their choices by a stated criterion, a small version of evaluating competing solutions systematically.

Roles (rotate each session)

- **Miner:** Extracts chips with the chosen tools, one tool at a time, and stops the instant the timer calls time. A different student mines the second cookie.

- **Surveyor and timer:** Traces the cookie outline on the grid before mining, counts the squares covered, runs the timer and announces each minute.
- **Accountant:** Records every cost and sale in the ledger as it happens and computes the profit.
- **Reclamation inspector:** Judges which chips count as whole or fragment, times the one-minute cleanup, and counts the squares with crumbs outside the original outline.

Materials

Item	Quantity	Per	Note
High-grade deposit: a small chocolate-chunk or extra-chip cookie, about 4 to 5 cm across (many visible chips)	1	group	Store-bought, individually bagged if possible. The price list assumes a claim of about 20 to 30 grid squares; if your cookies are larger, cut each one in half before class and mine a half cookie. Check allergy lists before buying.
Low-grade deposit: a cookie (or half cookie) of the same size with few chips, for example an oatmeal cookie with a few chips or a plain cookie brand with sparse chips	1	group	The two types should be similar in size; the difference should be the number of chips.
Centimeter grid paper (the mining claim)	2 sheets	group	
Flat toothpicks	4	group	
Round toothpicks	2	group	
Large paper clips (to straighten into a pick)	2	group	
Paper towels or a paper plate as the work surface	2	group	
Timer or clock with a second hand	1	group	
Disposable gloves (optional) and hand-washing access	1 pair	student	Nothing in this lab is eaten.
Recording sheet and calculator	1	student	

Estimated cost: 10 to 16 per class (an estimate; Estimate. Two packages of cookies (about \$4 to \$6 each) supply eight to ten groups; toothpicks, paper clips and grid paper are classroom stock; gloves add about \$3 if used.)

Safety

- Food allergies: cookies may contain wheat, dairy, soy, eggs and nuts or traces of them. Check the allergy list first and use the non-food alternative for any class with a severe allergy. Nothing is eaten during or after the lab.

- Toothpick points can puncture skin; mine with the tool pointed away from fingers and dispose of broken pieces in the trash, not on the floor.
- Keep the work surface on paper and wash hands after cleanup; crumbs on the floor are a slip hazard and attract pests, so wipe desks before leaving.

Teacher preparation and setup

1. Check the class allergy list (wheat, dairy, nuts, soy) before buying cookies; if any student has a severe food allergy, run the whole class on the play-dough-and-bead deposit described in the low-cost alternative instead.
2. Buy two cookie types of similar size that differ clearly in chip count; open one of each in advance to confirm the difference and to set your own expectation for the chip counts.
3. Calibrate once: trace one high-grade cookie on centimeter grid paper and run a quick ledger with your own chip count. At \$4 a square, a claim of 20 to 30 squares lets a chip-rich cookie make a profit, but a 7 cm cookie touches about 50 squares, so its land alone costs about \$200 and even a chip-rich one may lose money. Halve large cookies rather than changing the price list, so the q4 example still matches.
4. Print one grid sheet per cookie and the recording sheet per student; copy the price list onto the board so every group uses the same prices.
5. Make the rule explicit before cookies are handed out: nothing is eaten, hands are washed afterward, and all cookie material goes into the trash at the end.

Investigation design

Independent variable	Deposit grade (high-chip cookie versus low-chip cookie)
Dependent variable	Profit in dollars, and the actual grade (chips per square)
Controlled	Same price list for every group; Five-minute maximum mining time and a one-minute reclamation period; Tools only, no fingers; cookie stays on the paper; Same inspector rules for whole chips and fragments
Trials	One cookie of each grade per group; the class pools profits so that each grade has eight or more trials.
Comparison	High-grade versus low-grade profit; estimated grade (surface count) versus actual grade (total count).

Student procedure

1. Prospect before you buy. Look at the top surface of your high-grade cookie without touching it. Count the chips you can see and record the number. Then trace the cookie's outline on the grid paper and count every square the outline touches, including partial squares. That is your land area; the land costs \$4 per square.
2. Compute your estimated grade (visible chips divided by land squares) and record it. Decide which tools to buy from the price list (flat toothpick \$4, round toothpick \$6, straightened paper clip \$8; a broken tool must be replaced at full price) and record the tool cost.

3. Mine. The miner may use only the tools bought, may not use fingers to pry chips out, and may not lift the cookie off the paper. Mining time costs \$3 per minute, and any started minute counts as a full minute. Stop at five minutes at most. The inspector sorts what comes out: a whole chip (about pea-sized or larger, with little dough attached) sells for \$20; a fragment sells for \$8.
4. Reclaim. The inspector starts a one-minute timer. The miner uses the tools to push all cookie material back inside the original outline. When time is called, count the squares outside the outline that still hold crumbs; each costs \$4. Also record in words what the deposit looks like now compared with the start.
5. Compute profit: sales minus land, tools, time and reclamation. Then compute the actual grade: total chips found (whole plus fragments) divided by land squares. Compare it with your estimate from the surface.
6. Repeat steps 1 to 5 with the low-grade cookie and a different miner. You may change your tool choice and plan a shorter mining time if you think the deposit will not pay.
7. Draw the before-and-after outline for one cookie on the recording sheet. Clear all cookie material into the trash, wipe the desk and wash hands.
8. Answer the analysis questions individually, then compare profits across the class on the board: high-grade and low-grade cookies in two columns.

Expected observations

- High-grade cookies 4 to 5 cm across (20 to 30 squares) typically yield 10 to 20 chips and fragments and, at these prices, results from about break-even to a profit near \$200; low-grade cookies yield 3 to 8 pieces and lose money or roughly break even.
- Surface counts underestimate the chips in a thick cookie and overestimate them in a thin one; groups notice that prospecting from the surface is a rough guide.
- Paper clips extract whole chips faster but spread more crumbs; flat toothpicks break and must be replaced, which some groups discover only when the accountant adds the cost.
- After reclamation the cookie is a pile of crumbs inside the outline, and every group reports that the deposit could not be mined again.

Likely difficulties

- Students eat or taste the cookie. State the rule before cookies are handed out and collect all material in the trash at the end; this is a lab, not a snack.
- Disputes over whole chip versus fragment; the inspector's call is final, and the price difference keeps the stakes low.
- Groups forget to count partial squares as land; have the surveyor trace and count before any tool is bought.
- Chip counts vary a lot between cookies of the same brand, so some high-grade cookies lose money; use that as evidence that exploration involves risk even in a known region.

Structured debrief

1. Put every group's profit on the board in two columns. Most high-grade cookies earn money and most low-grade ones lose it or barely break even. Ask what single number separates the two columns: the grade. Then define ore as a concentration high enough to pay at today's prices, and point out that real ore grades for copper are below 1 percent, so the dough-to-chip ratio in even the low-grade cookie is far richer than real rock.
2. Hold up a reclaimed cookie. It is still in the outline but it is rubble, and the chips are gone. Connect to open-pit copper mines that fill with water, and to the standard's point that resource distribution is changing because of human removal. Ask whether any process in the room could put the chips back.
3. Use q4 to introduce cutoff grade: when the price rises, deposits that were not worth mining become ore, and old mine dumps sometimes get re-mined. When the price falls, mines close with ore still in the ground. Geology sets where the concentration is; economics sets whether it counts as ore.
4. Close with recycling (q7): copper in a dead phone is already concentrated, which is why recycled metal supplies a large share of new copper products. That is the closest thing to renewing a nonrenewable mineral resource.

Recording sheet: what students fill in

Lab 2 recording sheet: The cookie mine

Price list (same for every group; teaching prices, not real market values) — Land: \$4 per grid square touched. Tools: flat toothpick \$4, round toothpick \$6, straightened paper clip \$8; replace a broken tool at full price. Mining time: \$3 per started minute, 5 minutes maximum. Sales: whole chip \$20, fragment \$8. Reclamation: \$4 per square with crumbs outside the outline after one minute of cleanup.

Prospecting (before mining)

Deposit	Visible chips on top	Land squares touched	Estimated grade (chips per square)	Tools bought and cost	Planned mining minutes
High-grade cookie					
Low-grade cookie					

Mining ledger

Line	High-grade cookie	Low-grade cookie
Land cost (\$4 x squares)		
Tool cost (including replacements)		
Minutes mined x \$3		

Line	High-grade cookie	Low-grade cookie
Whole chips found x \$20		
Fragments found x \$8		
Total sales		
Squares with crumbs outside outline x \$4		
Total costs (land + tools + time + reclamation)		
Profit (sales minus total costs)		
Actual grade (all chips found per square)		

- ✎ Draw the outline of one cookie on its grid before mining and, beside it, what the same claim looked like after reclamation. Shade the squares that still had crumbs outside the outline and label the number of chips removed.

Answer: Two sketches: a traced outline on a grid with the chip count written, and the same outline after reclamation showing crumbs within it and shaded outside squares with their count. The number of chips removed should match the ledger.

Why: The drawing is a record of change in the land; check that the shaded squares match the reclamation line in the ledger.

- Before outline with land squares visible
- After sketch with spilled squares shaded and counted
- Chips removed labeled and consistent with the ledger

1. In words, describe what the deposit looked like after mining and cleanup compared with the start. Could it be mined again for the same resource?

Answer: The deposit is a pile of crumbs pushed back inside the outline; the chips are gone and the cookie cannot be reassembled. It could not be mined again for chips because the resource has been removed; only the waste remains.

Why: The point is that extraction empties the deposit; the land is changed even after reclamation.

- Describes the deposit as rubble with the chips removed
- States it cannot be mined again for the same resource

2. How close was your estimated grade (from the surface) to your actual grade? What does that tell you about prospecting from the surface?

Answer: Group-specific. Typically the surface count is lower than the total because chips are hidden inside; sometimes it is higher for a thin cookie. Surface prospecting gives a rough estimate, which is why real exploration drills test holes before buying a mine.

Why: Students should compare the two numbers and draw the conclusion that surface clues are a guide, not a measurement.

- Compares estimated and actual grade with numbers
- Concludes that surface prospecting is approximate

Analysis questions: answer key

3. Show the profit calculation for your high-grade cookie, line by line, and state whether the deposit was ore (worth mining) at these prices.

Answer: Group-specific. Example: land 22 squares $\times$ \$4 = \$88; paper clip \$8; 4 minutes $\times$ \$3 = \$12; sales 12 whole $\times$ \$20 = \$240 plus 6 fragments $\times$ \$8 = \$48, total \$288; reclamation 5 squares $\times$ \$4 = \$20; total costs \$88 + \$8 + \$12 + \$20 = \$128; profit \$288 – \$128 = \$160. Positive profit, so this deposit is ore at these prices.

Why: Check that every line is present and that profit equals sales minus all four costs. A negative profit with correct arithmetic earns full credit if the student concludes the deposit was not ore.

Also acceptable: Accept any correct line-by-line computation from the group's own ledger.

4. A low-grade cookie covered 22 squares, cost \$4 in tools, was mined for 3 minutes, produced 4 whole chips and 3 fragments, and left crumbs in 4 outside squares. Compute the profit. Then find the whole-chip price at which this deposit would just break even (fragments stay at \$8).

Answer: Costs: land 22 $\times$ \$4 = \$88; tools \$4; time 3 $\times$ \$3 = \$9; reclamation 4 $\times$ \$4 = \$16; total \$117. Sales: 4 $\times$ \$20 = \$80 plus 3 $\times$ \$8 = \$24, total \$104. Profit = \$104 – \$117 = –\$13 (a loss). Break-even: sales must equal \$117, so $4p + \$24 = \$117$, $4p = \$93$, $p = \$23.25$ per whole chip. At any price above about \$23.25 the same cookie becomes ore.

Why: This is the cutoff-grade idea in arithmetic: the deposit did not change, only the price. Check the subtraction and the division.

Also acceptable: Accept \$23 or \$23.25; accept 'about \$24' if the student rounds up to the first price that gives a profit.

5. Explain what 'ore' means using your two cookies. Why can the same rock be ore in one decade and not in another?

Answer: Ore is rock with enough of a valuable mineral that mining it earns more than it costs. The high-grade cookie had enough chips per square to pay for land, tools, time and cleanup, so it was ore; the low-grade cookie had the same costs but too few chips, so it was just rock. The same rock can switch sides when prices or costs change: if chip prices rise (q4) the low-grade cookie becomes ore; if cheaper tools or faster mining cut costs, the same thing happens; if prices fall, a mine can close with ore still in the ground.

Why: Full credit requires both halves: the concentration idea and the price or cost dependence.

- Defines ore in terms of concentration and profit
- Uses the two cookies as the contrast
- Explains that price or cost changes move the cutoff

6. In real copper mining the ore is crushed and the metal is separated, and the leftover rock and the pit remain. Which parts of the cookie model matched that, and which parts did not?

Answer: Matches: the valuable part (chips) is scattered through worthless material (dough); getting it out breaks up the surrounding material; the leftover rubble and the disturbed claim remain; cleanup costs money and does not restore the original. Mismatches: real ore has far lower grades (under 1 percent copper), so almost everything mined is waste; the metal must be crushed and chemically separated, which the model skips; real pits can fill with contaminated water and real reclamation takes years; and the cookie shows nothing about the geologic process that concentrated the chips in the first place.

Why: Evaluating a model's limits is part of the modeling practice; at least two of each are required.

- At least two accurate matches
- At least two accurate mismatches, including grade or processing

7. A mining company has two cookies' worth of ore left in a region and no new deposits. Describe two things the company, or the people who buy copper, could do when the deposits are gone, and say which of them comes closest to renewing the supply.

Answer: They could explore for new deposits elsewhere (which moves the resource map but does not create copper), mine lower-grade rock if prices rise, or recycle copper from old wires, pipes and electronics. Recycling comes closest to renewal: the metal in discarded products is already concentrated, so it can be used again. It does not make copper ore renewable, because no new ore forms on a human timescale, but it keeps mined copper in use and makes the use of copper more sustainable.

Why: Connects the nonrenewable label to the one practical loop, recycling; exploring elsewhere is the 'distribution changes' idea.

- Two responses named
- Recycling identified as the option closest to renewal, with the reason
- Does not claim that recycling makes copper ore renewable

8. The reclamation charge was small compared with chip sales. If it were \$40 per square instead of \$4, how would your group have mined differently, and why might a community want the charge to be high?

Answer: With a \$40 charge, spilling even three squares would cost \$120, so the group would mine more carefully and slowly, perhaps with a toothpick instead of a paper clip, keep crumbs inside the outline as they went, and might skip the low-grade cookie entirely. A community wants a high charge because the land, water and wildlife near a mine are theirs after the company leaves; a high reclamation cost makes the company plan the cleanup from the start rather than leave a pit.

Why: Shows that constraints change the design of the operation, the engineering idea in the lab.

- Describes a specific change in method or decision
- Gives a reason a community would set the cost high

Individual evidence of learning

Each student submits their own prospecting table, ledger, before-and-after drawing and answers to q1 through q8. The ledger and q3 are the evidence for computing profit from grade and costs; q5 and q7 are the evidence for the meaning of ore and for how human removal changes the resource map.

Assessment criteria

Criterion	Proficient looks like
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Ledger and arithmetic	All cost and sales lines recorded for both cookies, profit computed correctly, actual grade computed as chips found per square.
Meaning of ore	Explains ore as a concentration high enough to pay at current prices and shows (q4) how a price change moves a deposit across the line.
Human removal and reversibility	Describes the mined deposit as empty and the land as changed, and identifies recycling as the practical way to get more metal once deposits are gone.
Model evaluation	q6 names at least two matches and two mismatches between the cookie and real mining.

Accessibility adaptations

- Pre-fill the land-cost row and provide a calculator for students who need more support; the arithmetic is the same for everyone and the ledger has one line per cost.
- Allow the miner role to go to a student who wants to work with their hands and the accountant role to a student who prefers quiet work; rotate for the second cookie.
- For students with limited fine-motor control, allow the paper clip as the only tool and extend mining time at no charge; for low vision, use large chunk cookies and high-contrast grid paper.
- Accept a spoken answer recorded on a device for q5 and q6.

Low-cost alternative

Make deposits from a flattened ball of play dough with small beads pressed in (many beads for high-grade, few for low-grade); beads are reusable and the activity is allergy-safe. Use a single toothpick type if that is all you have and set its price at \$5.

Model limitations

A cookie is far richer than any real ore: even the low-grade cookie is tens of percent chips by volume, while copper ore is well under 1 percent copper. The chips are already pure, whereas real ore must be crushed and processed, which is the costliest and most polluting step. The model does not show the geologic process that concentrated the chips, groundwater pollution from a pit, or the years a real reclamation takes. Prices are teaching values. This activity has not been physically tested by the authors; chip counts and the profit ranges in expected Observations are estimates for typical store-bought cookies.

Teacher notes

Set the prices on the board before cookies appear and hold to them; the arithmetic only works if every group uses the same list. Expect a few high-grade cookies to lose money because chip counts vary; treat that as a lesson about exploration risk rather than a failure. If the class finishes early, pool the actual grades for each cookie type and compute the class average, then ask how many squares a cookie of each grade would need to cover to earn \$100. For allergy-free classes the play-dough version works identically and is reusable.