

Twelve Places, One Cycle: An Evidence Jigsaw on Sun, Cooling and Gravity

Learning target: I can use evidence from many places on Earth to sort water cycle processes by their driver, trace several different routes a water molecule could take, and defend the idea that the cycle has no fixed order.

Collaborative investigation

About 55 min

Jigsaw

MS-ESS2-4 · practice

collaboration

discussion

data analysis

Standards connections

MS-ESS2-4 (practice): MS-ESS2-4 is a California Grade 6 PE revisited here. Groups assemble observations from twelve locations into a driver chart and traced routes, which is the evidence-gathering and model-organizing work behind the PE; the individual section checks that each student can explain the drivers alone.

Purpose: practice · **Time:** about 55 minutes · **Format:** jigsaw

Answers with reasoning

Twelve evidence cards: observations from twelve places

1 Card 1: Ocean surface, sunny afternoon

A buoy reports surface water at 24 °C and the air just above it getting steadily more humid through the afternoon. The water never comes close to boiling. On a dry, windy day the surface temperature drops slightly even in full sun, as if something were carrying energy away.

2 Card 2: Oak branch with a bag over it

A clear plastic bag tied over a leafy branch collects 30 mL of water in one sunny day and 5 mL on a cloudy day. Under a microscope the underside of each leaf shows thousands of tiny pores. A branch with its leaves removed collects almost nothing.

3 Card 3: Glacier edge, July

Meltwater streams at the foot of the ice run hardest at about 4 p.m. and slow to a trickle before dawn. On an overcast day the afternoon peak is much smaller. The ice surface is dirty gray in late summer and melts faster than the clean white snow beside it.

4 Card 4: Air rising over a ridge

A weather balloon shows that air pushed up the side of a mountain cools by roughly 1 °C for every 100 m it climbs. The flat bottom of the clouds sits at exactly the height where the air has cooled enough that it can no longer hold all of its vapor. Above that height, the balloon's sensor is wet.

5 Card 5: Kitchen window, winter morning

Indoors the air is 21 °C and moist from cooking; outside it is −2 °C. The inside of the window is covered in liquid drops by morning, while the outside of the window is dry. The drops are pure water even though the air carried smells of soup.

6 Card 6: Car windshield, clear cold night

The windshield is dry and clean at sunset. After a clear night at −5 °C it is covered with feathery ice crystals at dawn. No drops of liquid were ever seen on it, and no rain or snow fell.

7 Card 7: Inside a rain cloud

Cloud droplets are about a hundredth of a millimeter across and float on rising air. They bump into one another and merge. When they reach about a millimeter across they begin to fall. High-speed photos show large falling drops flattened on the bottom like a bun, and the very largest break apart in the air.

8 Card 8: Two slopes in the same storm

A rain gauge records 20 mm of rain. On a grassy hillside, water begins trickling into the ditch at the bottom after about an hour. On a paved parking lot beside it, water is streaming into the storm drain within two minutes, and the stream is much larger.

9 Card 9: Two soil columns

A cup of water poured onto a tube of sandy soil disappears into it in seconds and drips out the bottom a minute later. The same cup poured onto a tube of tight clay sits on top as a pool for most of an hour. Both tubes are held upright; when the sandy tube is laid flat, the dripping stops.

10 Card 10: Valley well and a spring

The water level in a farm well rises about two weeks after heavy rain on the hills above, not during the rain. Harmless dye poured into a sinkhole on the hill appears at a spring 3 km downhill 40 days later. The spring keeps flowing through a rainless summer.

11 Card 11: Fog net on a desert hillside

On foggy mornings a mesh net stretched between poles becomes wet, drops run down the mesh into a gutter and the gutter drains into a tank. The droplets in the fog are far too small to fall as rain on their own. Output is highest on windy fog days and zero on clear days.

12 Card 12: Earth's water inventory

Scientists estimate that about 96.5 percent of Earth's water is in the oceans, 1.74 percent is frozen in glaciers and ice caps, 1.69 percent is groundwater, 0.013 percent is in lakes, and only about 0.001 percent is in the atmosphere at any moment. Yet it rains or snows somewhere on Earth every day, and a typical water molecule stays in the air for only about a week to ten days before falling out.

Part A: Expert round (one set per person)

1. For each of your three cards, write: the process it shows (or the storage place), the driver (sun's energy, cooling, or gravity), and the single sentence of evidence on the card that proves the driver. Agree on these with the other experts who hold your set.

Answer: Set A. Card 1: evaporation; sun's energy; the water is 24 °C, never near boiling, yet the air above gains humidity. Card 2: transpiration; sun's energy; 30 mL on a sunny day versus 5 mL on a cloudy day. Card 3: melting; sun's energy; melt peaks at 4 p.m. and nearly stops before dawn. Set B. Card 4: condensation (cloud formation); cooling; the cloud base is where the rising air has cooled enough. Card 5: condensation on a surface; cooling; drops form on the cold inside of the window. Card 6: crystallization by deposition (gas to solid); cooling; crystals formed with no liquid ever seen. Set C. Card 7: precipitation; gravity; drops fall once they are big enough, with air resistance flattening and breaking the largest. Card 8: runoff; gravity; water flows downhill to the ditch and drain, faster on pavement. Card 9: infiltration; gravity; water soaks down through sandy soil and the dripping stops when the tube is laid flat. Set D. Card 10: groundwater flow through an aquifer; gravity; dye travels 3 km downhill in 40 days, and the well rises two weeks after the rain. Card 11: fog (condensed droplets) collected by a net and drained by gravity; cooling made the fog, gravity moves the merged drops. Card 12: storage; the amounts stored in each place; it shows the atmosphere stores very little but moves water through quickly.

Why: Each card contains one line that isolates the driver (a sunny-versus-cloudy contrast for the sun; water appearing on something cold for cooling; motion that is downward and stops when there is no 'down' for gravity).

Also acceptable: Accept 'freezing from vapor' or 'deposition' for Card 6; accept 'cooling then gravity' for Card 11.

- Process or storage named for all three cards
- Driver named for all three
- A specific evidence sentence quoted or paraphrased for each

Part B: Home group task

1. Each expert teaches their three cards. Listeners write the process and driver for every card in the group table below.
2. Lay the twelve cards on the desk in three columns: sun's energy (water gains energy), cooling (water gives off energy), gravity (water moves down or downhill). Two cards are about storage or a built device rather than one process; decide together where they belong and write a note explaining your choice.
3. Check every column with the test question: for the sun column, does the card's evidence change with sunlight? For the cooling column, does the card show water appearing where it is cold? For the gravity column, does the card show water moving down, and does it stop when there is no 'down' (Card 9)?
4. Trace three routes a single water molecule could take through at least five different cards each, writing the card numbers in order (for example 1, 4, 7, 8, 10). No two routes may share more than two cards, and at least one route must never visit the ocean.
5. Prepare a one-minute defense of this claim: 'The water cycle has no fixed order.' Use at least two of your routes and Card 12 as evidence. Every member must be able to give the defense.

Group record (fill in)

Card	Process or storage	Change of state (if any)	Driver	Evidence sentence (short)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				

2. Write your three routes as lists of card numbers, each with a one-line description of the molecule's trip. Mark the route that never visits the ocean.

Answer: Example routes. Route A (ocean route): 1, 4, 7, 9, 10: evaporates from the ocean, condenses into a cloud as the air rises over the ridge, falls as rain, soaks into sandy soil, and flows underground to the valley well and spring. Route B (never visits the ocean): 2, 4, 7, 3, 8: transpired by the oak, condenses in a cloud over the ridge, falls as snow on the glacier, melts on a July afternoon, and runs downhill into a ditch. Route C: 1, 6, 8, 9, 2: evaporates from the ocean, is carried inland and deposits as frost on a windshield on a clear, cold night, melts in the morning sun and runs off the car across the pavement, soaks into sandy soil at the edge of the lot, and is taken up by the oak's roots and transpired. Check the sharing rule: A and B share only Cards 4 and 7, A and C only Cards 1 and 9, B and C only Cards 2 and 8. Any three routes of five or more cards in a physically possible order, with no pair of routes sharing more than two cards and one route avoiding Card 1 and the ocean, earn full credit.

Why: The point is that many orders are physically possible. Check each route for physical sense: cooling cards must come after a card that put vapor in the air (1, 2, or an earlier evaporation), and gravity cards must follow water being in a position to fall or flow.

Also acceptable: Routes that use Card 11 (fog net) as a stop or Card 12 as a 'storage' stop are acceptable if explained.

- Three routes of at least five cards
- Each in a physically possible order
- No two routes share more than two cards
- One route never visits the ocean

3. Record the challenge the neighboring group made to your route and how your group answered it. If they found a step that really could happen in a different order, say so and explain why that supports the 'no fixed order' claim rather than hurting it.

Answer: Open response. Example: 'They said our molecule could have fallen straight back into the ocean instead of on the hill (Card 7 then Card 1 again). We agreed; that is another possible route, which is exactly the point: the cycle has no fixed order, and water often skips steps or repeats them.'

Why: A successful challenge strengthens the no-fixed-order claim; the key is whether the group recognized this.

Also acceptable: If the neighbors found no alternative order, accept a sentence proposing one the group thought of themselves.

- Records a specific challenge
- Records the group's response
- If the challenge was valid, explains that it supports the claim

Part C: Individual accountability (complete alone)

4. Which card proves that evaporation happens far below boiling? Quote the evidence and explain what the slight cooling of the surface on a windy day tells you about where the energy went.

Answer: Card 1. The ocean surface was 24 °C, far below 100 °C, yet the air above kept gaining humidity, so water was leaving the surface as vapor. The slight cooling on a windy day shows that evaporation carries energy away: the fastest molecules leave, taking their energy with them, so the water left behind is a little cooler. Wind speeds this up by sweeping the vapor away so more can escape.

Why: Below-boiling evaporation plus the energy-leaves-with-the-vapor idea (qualitative; no latent heat numbers).

Also acceptable: Accept 'the same reason sweat cools you.'

- Card 1 identified with the 24 °C evidence
- Explains surface cooling as energy leaving with the escaping molecules

5. Cards 4, 5 and 6 all belong in the same column. What do they have in common, and what is the one difference between Card 6 and the other two?

Answer: All three show water vapor turning into something you can see because the air or a surface got cold: water gives off energy and its molecules slow and stick together (the cooling column). The difference: on Cards 4 and 5 the vapor became liquid droplets (condensation), while on Card 6 it became solid ice crystals directly, with no liquid stage (deposition, which the lesson calls crystallization).

Why: Common driver (cooling, energy given off) and the gas-to-liquid versus gas-to-solid distinction.

Also acceptable: Accept 'Cards 4 and 5 make water, Card 6 makes ice.'

- Common driver: cooling, vapor gives off energy
- Card 6 is gas to solid without a liquid stage

6. Using evidence from at least three cards (one from each driver column), explain why the water cycle needs both the sun's energy and gravity, and what would happen to the cycle if either one stopped.

Answer: Model answer: The sun's energy is what lifts water: Card 1 shows the ocean surface sending vapor into the air at only 24 °C, and Card 2 shows a tree transpiring six times as much water on a sunny day as on a cloudy one. Cooling turns that vapor back into droplets and crystals (Card 4's cloud base sits exactly where the rising air got cold enough). Gravity is what brings water down and moves it across the land: Card 7's drops fall once they are heavy enough, Card 8's runoff races downhill, and Card 10's dye takes 40 days to travel 3 km downhill underground. If the sun stopped, no new vapor would be made; the clouds would rain out once, the rivers and groundwater would drain to the ocean, and then everything would sit still. If gravity stopped, vapor would still form but nothing would fall or flow back down; the air would hold its clouds and the land would dry out. Both are needed because one does the lifting and the other does the returning.

Why: Full credit requires at least one card from each column cited correctly, both 'stop' cases reasoned through, and the lifting-versus-returning idea.

Also acceptable: A student who says the cooling column is really 'the sun's energy leaving again' is making a sophisticated and correct point.

- Evidence from a sun card, a cooling card and a gravity card
- Explains what stops if the sun stops
- Explains what stops if gravity stops
- States the complementary roles

7. Card 11 describes a fog net. Name every water cycle process that happens from the time ocean water becomes fog to the time water reaches the tank, and say which driver is responsible for each step.

Answer: Evaporation from the ocean (sun's energy); the moist air cools as it moves over cold water or rises, and the vapor condenses into fog droplets (cooling); wind, not gravity, blows the fog into the net, where the tiny droplets stick and merge into drops big enough to run; gravity then pulls the drops down the mesh into the gutter and down the gutter into the tank (gravity, like runoff). The net replaces the step that fog cannot do on its own: its droplets are too small for gravity to pull them down as rain.

Why: Three water cycle steps plus the engineered one; the key insight is that the net makes droplets large enough for gravity to move.

Also acceptable: Accept 'wind brings the fog' as a non-water-cycle driver if the student labels it as such.

- Evaporation (sun)
- Condensation into fog (cooling)
- Drops merging on the net then draining (gravity)
- Notes that fog droplets are too small to fall on their own

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Expert teaching (Part A)	All three cards taught with the correct process, driver and a quoted evidence line; listeners' tables match.	Three cards taught correctly; one evidence line vague or one listener's table has an error.	One card's driver wrong, or evidence not tied to the driver.	Cards read aloud without identifying process or driver.

Driver chart and group table	All twelve cards placed and recorded correctly, with a written note on Cards 11 and 12 and the three test questions applied.	All cards placed; one error in change of state or one missing evidence sentence.	Two or more cards in the wrong column, or the table half complete.	Cards left unsorted or sorted by a feature that is not a driver (for example, indoors versus outdoors).
Routes and defense	Three physically possible routes of five or more cards, sharing no more than two, one avoiding the ocean; the defense uses two routes and Card 12 and every member can give it; the challenge is answered with evidence.	Three valid routes; defense given by some members or without Card 12.	Routes are too short, share too many cards, or contain a step that is physically impossible (cooling before any vapor exists).	No routes, or one route copied from a textbook diagram.
Individual accountability (Part C)	All four Part C answers are accurate, cite cards by number and evidence, and show the student understands the drivers, not just the group's chart.	Three of four accurate with card evidence; one thin or partly incorrect.	Two accurate; others restate the group's chart without reasoning.	Part C mostly blank or inaccurate.

Teacher notes

Card facts are realistic and consistent with the lesson: rising air cools at roughly 1°C per 100 m when dry (Card 4, stated as 'roughly'); cloud droplets are about 0.01 mm and raindrops begin to fall near 1 mm (Card 7; no breakup size is given because sources disagree, and raindrops are not teardrop-shaped); Card 12's percentages are the USGS/Gleick figures, and the average residence time of water in the atmosphere is commonly given as about nine days. Card 2 fixes the textbook's page 235 wording: water evaporates inside the leaf and exits the stomata as vapor. Card 6 is deposition, the gas-to-solid case the lesson folds into 'crystallization' (page 237 / PDF 273). Expected sort: sun 1, 2, 3; cooling 4, 5, 6; gravity 7, 8, 9, 10; Card 11 spans cooling and gravity; Card 12 is storage. Print the cards large enough to move around; the three-column layout on the desk is most of the learning. Fog catchers are the lesson's engineering strand (printed 242-243 / PDF 278-279) and return in Worksheet 9.

Scaffold offered to students: If the sorting stalls

Use the fastest clue on each card. Does the card mention sunlight, afternoon, or a sunny versus cloudy difference? It belongs under the sun's energy. Does water appear on something cold, or where air has cooled? It belongs under cooling. Does the card describe water moving downhill, dripping, draining or falling? It belongs under gravity. Cards 11 and 12 are special: Card 11 contains several processes, and Card 12 is about how much water is stored where. Put those two aside and sort them last, as a group.

Extension: The thirteenth card

Write a thirteenth evidence card for a place the deck does not cover (ideas: a snowfield on a cold, dry, sunny day; a desert playa after a flash flood; a greenhouse; the inside of a cave). The card must contain at least one observation that identifies the driver and at least one number. Then write its key: the process, the change of state if any, the driver, and the route it could join. Trade cards with another group and sort each other's.