

Reading the Schoolyard: Evaporation and Transpiration in Sun and Shade

Investigation question: How much faster does water leave an open tray, and a living plant, in full sun than in shade, and what does that tell us about what powers the upward half of the water cycle?

Classroom field investigation

Groups of 4

2 sessions

Setup 10 · Activity 65 · Cleanup 10 min

MS-ESS2-4 · practice

Scientific purpose

Students take the water cycle outdoors. They set out identical water trays in sun and shade, tie clear bags over leafy branches in sun and shade, add a leafless control, and come back a day later to measure how much water left each one. They also walk the schoolyard looking for evidence of evaporation, condensation, runoff and infiltration. The measurements turn 'the Sun drives evaporation' into a number students collected themselves.

Why this helps students with this chapter

Evaporation and transpiration are invisible, so students have only been told about them. A tray that loses a measurable depth of water in a day and a bag that fills with droplets on a leafy branch, but stays dry on a bare stick, make the two processes real. Because the only difference between the pairs is sunlight, the comparison isolates the Sun's role, and the evidence walk connects the processes to the puddles, damp soil and drains students pass every day.

Standards connections

MS-ESS2-4 (practice, evidence that energy from sunlight drives evaporation and transpiration): The sun-versus-shade comparison gives students first-hand data that sunlight speeds the liquid-to-vapor half of the cycle and that plants are part of it; the data feed the models students develop in W4 and Lab 3, which carry the assessment. This PE is a California Grade 6 expectation revisited in this seventh-grade lesson.

Roles (rotate each session)

- **Site scout:** Chooses the sunny and shaded spots within the teacher's boundaries, checks that they will stay sunny or shaded for most of the day, records the air temperature at each, and draws the site map.
- **Tray technician:** Levels and fills both trays, measures the water depth at the center to the nearest millimeter at the start and at the end, and weights the trays so they do not blow away.
- **Bag technician:** Counts the leaves on each branch, slides on the bags, ties them loosely, hangs a bottom corner down to collect water, and pours the collected water into the measuring syringe or cylinder at the end.
- **Recorder and timekeeper:** Writes every time, temperature and measurement in the table as it is taken, keeps the group on schedule, and leads the evidence walk notes.

Materials

Item	Quantity	Per	Note
Identical shallow trays, about 20 to 30 cm across (aluminum baking pans, plastic food-container lids with a rim, or plant saucers)	2	group	The two trays in a pair must be the same size and color.
Measuring cup or 500 mL bottle for filling the trays	1	group	
Ruler marked in millimeters	1	group	
Clear gallon-size zip-top bags	3	group	Two for leafy branches, one for the leafless control.
String, twist ties or soft garden tape	3 pieces, about 30 cm	group	
10 mL syringe (no needle) or a 10 to 25 mL graduated cylinder	1	group	
Thermometer (air temperature)	1	group	One per class shared in turns also works.
Small rocks or weights for the trays	2	group	
Masking tape and marker for labeling trays and bags with the group name	1 each	class	
Clipboards and the recording sheet	1 set	student	
Teacher-approved leafy shrubs or trees with a branch in sun and a branch in shade, or two potted plants of the same kind	access to 1 plant	group	

Estimated cost: 8 to 15 per class (an estimate; Estimate. A box of gallon zip bags (about 5 dollars), string and tape (about 3 dollars) and disposable aluminum pans if no trays are available (about 5 dollars). Rulers, syringes and thermometers are typical science stock.)

Safety

- Only teacher-approved plants may be used. Never put a bag on, or handle, an unmarked plant: oleander is common in California landscaping and is poisonous, poison oak grows wild at the edges of many school grounds, and plants with milky sap can irritate skin and eyes.
- Bags go over branches only, never over or near anyone's head or face. Keep the bags away from younger students who may be in the yard.
- On hot days wear hats, use sunscreen, carry water and limit time in full sun to the measurements. Watch for bees and wasps around flowering plants; do not swat.
- Stay inside the marked boundaries and within sight of the teacher. No climbing to reach branches.
- Do not eat or drink anything collected, and wash hands after handling plants, soil and bags.
- Be gentle with living plants: loose knots, no broken branches, and remove every bag within 24 hours so leaves do not overheat or rot.

Teacher preparation and setup

1. Walk the schoolyard a day ahead and choose the plants. Pick common, non-toxic, non-thorny shrubs or trees with branches at student height, and rule out oleander, poison oak, any plant with milky or irritating sap, and anything on a slope or near traffic. Mark the allowed plants with flagging tape.
2. Choose a flat sunny area and a flat shaded area (north side of a building or under a dense tree) within sight of each other, and check at midday that the sunny spot really stays in sun.
3. Check the forecast. Rain, strong wind or a frost will spoil the trays; reschedule rather than run in bad weather. A warm, clear, calm day gives the largest and clearest differences.
4. Print the recording sheet and the evidence-walk table; put the group's boundaries and the collection time on the board.
5. Tell the custodian and the office that bags and trays will be outside overnight with a sign that says 'Science experiment, please leave until tomorrow at [time]'.
6. Have the groups practice tying a bag on an indoor plant or a broom handle so that the knot is loose enough not to crush the stem.

Investigation design

Independent variable	Location: full sun versus shade, for both the open trays and the bagged branches
Dependent variable	Depth of water lost from each tray (mm, converted to mm per hour) and volume of water collected in each bag (mL, converted to mL per leaf)
Controlled	Same tray size, color and starting depth; Same plant species and about the same number of leaves in each bag; Same bag type, tied the same way, for the same number of hours; Trays and bags set out and measured at the same times
Trials	One sun-shade pair of trays and one pair of bags per group; the class pools 6 to 8 pairs on the wall chart to see whether the pattern holds across sites and groups.
Comparison	The leafless control bag in sun shows how much water a bag collects when no leaves are inside; the shaded tray and bag show how much water leaves without direct sunlight.

Student procedure

1. Session 1, in class (5 minutes). Write your prediction in q1: which tray will lose more water, which bag will collect more, and why, in water cycle terms.
2. Outdoors: the Site scout chooses the sunny spot and the shaded spot and records the air temperature at each. Draw the site map, including the Sun's direction and where the shade falls now.
3. Tray technician places one tray in each spot on level ground, weights it, fills it with the same amount of water (enough for about 10 mm depth), and measures the depth at the center to the nearest millimeter. Recorder writes the depth and the time for each tray.
4. Bag technician picks a leafy branch end in sun and one in shade on the same plant (or on two plants of the same kind), counts and records the leaves inside each bag, slides a dry bag over each branch end,

ties the mouth loosely around the stem, and arranges the bag so one bottom corner hangs lowest. Tie the third bag the same way on a leafless twig or a stick in the sun; this is the control.

5. If there is time at the end of the period or after lunch, check the bags without opening them and note any fog or droplets, and glance at the trays. Record the time of the check.
6. Session 2, the next day at about the same time (25 minutes outdoors). Record the weather and the air temperatures again. Measure each tray's depth at the center the same way and record the end time.
7. Open each bag at its lowest corner over the syringe or cylinder, pour out and measure the collected water to the nearest 0.5 mL. Record the mL and whether the leaves look healthy. Remove the string and bags carefully.
8. Evidence walk (10 minutes): walk the allowed area and record at least four signs of water cycle processes, with the process and its driver, in the evidence table (for example damp soil in shade but dry in sun, dew on grass, a shrinking puddle, water stains below a drain spout, moss on a north wall).
9. Back in class: compute depth lost for each tray and divide by the hours to get mm per hour; compute mL per leaf for each bag. Copy your group's results to the class table and answer the analysis questions.

Expected observations

- On a warm, clear day a 10 mm tray in full sun typically loses several millimeters over a school day plus night, while the shaded tray loses noticeably less; the sun-to-shade ratio is often around 2 to 3 but varies with wind and humidity.
- The sunny leafy bag fogs within an hour and holds a few milliliters by the next day; the shaded leafy bag holds less; the leafless control stays dry or holds only a trace.
- Leaves in the sunny bag may look limp or warm if the bag was left on too long, which is why the bags come off within 24 hours.
- Evidence walks usually turn up damp soil on the shaded side of buildings, dry soil in sun, water stains under spouts and drains, dew on morning grass, and shrinking puddles after sprinklers run.

Likely difficulties

- The 'sunny' spot falls into shade in the afternoon. The Site scout should check where shadows will move; a spot on the south side of the yard away from buildings is safest.
- Reading depth to 1 mm in a shallow tray is hard. Measure at the center with the ruler held vertical, read at eye level, and take two readings.
- A bag tied too tight crushes the stem; one tied too loose lets vapor escape. Practice on a broom handle first and aim for snug, not strangled.
- Rain, sprinklers or a passing dog can empty or fill a tray. Note anything unusual in the table and treat that tray's number as unreliable rather than deleting it.
- Students count a dozen leaves on one branch and forty on the other. Match leaf counts as closely as possible and always report mL per leaf, not just mL.

Structured debrief

1. Pool the tray rates on the board. Most groups should find the sunny tray losing water two or more times faster than the shaded one; ask why the ratio is not the same for every group (wind, partial shade, warm pavement under one tray, a tray that was not level).
2. Hold up a leafy sun bag with its droplets next to the dry control. Ask the room: where did this water come from? Lead students from soil water, up the stem, to evaporation inside the leaf, out through the stomata as vapor, to condensation on the cooler plastic. The control rules out the bag itself, dew and rain as the source.
3. Connect the two halves: the tray is evaporation from open water (most of the atmosphere's moisture comes from oceans, lakes and rivers), and the bag is transpiration (most of the rest). Both ran faster in the Sun, which is the lesson's main claim with the class's own numbers behind it.
4. Close with the evidence walk. Sort the class's observations into Sun-driven, gravity-driven and cooling, and note which processes nobody found evidence of (usually infiltration and groundwater, which happen out of sight); ask what evidence would reveal them (a dry drain the day after rain, a spring, a well).

Recording sheet: what students fill in

Lab 2 recording sheet: Evaporation and transpiration in sun and shade

Record times, temperatures and measurements as you take them. Depths to the nearest millimeter, volumes to the nearest 0.5 mL. Answer q1 before you go outside.

1. Prediction: which tray will lose more water, and which bag will collect more? Explain both predictions using what you know about evaporation and energy from the Sun.

Answer: The sunny tray should lose more water and the sunny leafy bag should collect more. Sunlight adds energy to the water, so more molecules at the surface move fast enough to escape as vapor; in the leaf, more energy means faster evaporation inside the leaf and more vapor leaving through the stomata to condense on the bag.

Why: Any prediction earns credit if it is reasoned; the expected reasoning is energy from sunlight raising the rate of evaporation and transpiration.

- States a prediction for both trays and bags
- Links the prediction to energy from sunlight and evaporation

Site and weather

	Start (session 1)	Check (optional)	End (session 2)
Date and time			
Air temperature, sunny spot (°C)			
Air temperature, shaded spot (°C)			
Sky (clear / partly cloudy / overcast)			
Wind (calm / breezy / windy)			

-  Site map: sketch the area from above. Mark the two trays, the three bagged branches, the Sun's direction at setup, and shade the parts that were in shadow when you set up.

Answer: An overhead sketch with the sunny spot and the shaded spot marked, the two trays and three bagged branches labeled (sun, shade, control), an arrow or symbol for the Sun's direction at setup, and the shaded areas hatched or shaded in.

Why: The map documents the independent variable; it lets the group and the teacher judge later whether the 'sunny' site really stayed sunny.

- Both trays and all three bags placed and labeled
- Sun direction and shade at setup shown

Evaporation trays

Tray	Start depth (mm)	End depth (mm)	Depth lost (mm)	Hours between measurements	Rate (mm per hour)
Sun					
Shade					

Transpiration bags

Bag	Leaves inside	Fog or drops at the check? (none / some / lots)	Water collected (mL)	mL per leaf	Leaves healthy at the end? (yes/no)
Leafy branch, sun					
Leafy branch, shade					
Leafless control, sun	0				

Evidence walk: signs of the water cycle in the schoolyard

Where	What we saw	Water cycle process	Driver (Sun / gravity / cooling)

2. Describe what you found in the three bags when you collected them. What does the leafless control bag tell you about where the water in the leafy bags came from?

Answer: The sunny leafy bag held drops of water on its inside and a few milliliters in the corner; the shaded leafy bag held less; the leafless control was dry or nearly dry. Because the control bag was tied the same way in the same sun and collected almost nothing, the water in the leafy bags must have come from the leaves, not from the bag, dew, rain or the air that was in the bag.

Why: This is the logic of a control: same conditions, missing the one thing being tested. Full credit uses it to rule out other sources.

- Reports the three bags' results
- Uses the dry control to conclude that the leaves were the source

Analysis questions: answer key

3. Calculate the evaporation rate for each tray in mm per hour, then calculate how many times faster the sunny tray lost water than the shaded tray (sun rate $\div$ shade rate). Show your work and the units.

Answer: Worked example: sunny tray 10 mm to 6 mm over 22 hours: $4 \text{ mm} \div 22 \text{ h} = 0.18 \text{ mm per hour}$. Shaded tray 10 mm to 8 mm over 22 hours: $2 \text{ mm} \div 22 \text{ h} = 0.09 \text{ mm per hour}$. Ratio: $0.18 \div 0.09 = 2.0$, so the sunny tray lost water about twice as fast. Students report their own numbers; ratios between about 1.5 and 4 are typical.

Why: Check that the hours match the recorded times, that both rates carry mm per hour, and that the ratio divides sun by shade. A ratio below 1 means the shaded tray lost more and should prompt a look at the notes (wind, tipping, a shaded tray on warm pavement).

Also acceptable: Accept rates in mm per day if the hours are converted consistently; the ratio is unchanged.

4. Trace the water in the sunny leafy bag from the soil to the drops in the bag. Name each step, the change of state where there is one, and what drove it.

Answer: Liquid water in the soil enters the roots and moves up the stem to the leaves (liquid, no change of state, pulled up as water evaporates above). Inside the leaf, water evaporates from the surfaces of cells into the leaf's air spaces (liquid to vapor, energy in, from sunlight warming the leaf). The vapor leaves through the stomata into the bag (still vapor, invisible). The bag's plastic is cooler than the air inside, so the vapor condenses on it as droplets (vapor to liquid, energy released, caused by cooling). The droplets merge and run down to the lowest corner under gravity (liquid, moved by gravity).

Why: The key accuracy point is that evaporation happens inside the leaf and water exits the stomata as vapor, not as liquid. Full credit needs the two changes of state with their energy direction and the gravity step.

- Evaporation placed inside the leaf, exit through stomata as vapor
- Condensation on the cooler bag with energy released
- Gravity collecting the drops at the low corner

5. The water in the trays never came close to boiling, yet it left. Use the particle model to explain how liquid water in the tray became vapor, and why the sunny tray did it faster.

Answer: Molecules in the liquid are close together but moving at a range of speeds. At any temperature a few at the surface move fast enough to break away and become vapor; that is evaporation, and it needs no boiling. Sunlight adds energy, so more molecules reach escape speed each second and the sunny tray loses water faster. Boiling is different: vapor bubbles form throughout the liquid at 100 °C, which never happened here.

Why: This is the chapter's central misconception repair. Credit needs the surface-escape idea and the link between added energy and a faster rate.

- Evaporation as escape of the fastest surface molecules at any temperature
- Sunlight raises the rate by adding energy
- Distinguishes evaporation from boiling

6. Look at the class table. Did every group find the same direction of difference between sun and shade? Give two reasons the sizes of the differences vary from group to group, and say whether those reasons weaken the main conclusion.

Answer: Usually every group finds sun greater than shade, but the ratios differ. Reasons: the sunny spots got different hours of direct sun as shadows moved; wind was stronger at some sites and carries vapor away faster; some trays sat on warm pavement and others on grass; leaf counts and plant species differed between bag pairs; some trays were not level, which changes the center depth. These reasons change the size of the difference, not its direction, so the main conclusion (sunlight speeds evaporation and transpiration) still stands; a single reversed group would need its notes checked for a disturbance.

Why: Students should distinguish variation in size from variation in direction, and should treat the pooled class data as stronger than any single pair.

- Reports whether the direction agreed across groups
- Gives two specific sources of variation
- Judges that the variation does not overturn the main conclusion

7. A large tree can carry tens of thousands of leaves. Use your sunny bag's mL per leaf to estimate how many liters of water a tree with 20,000 leaves might move into the air in the same number of hours (1 L = 1,000 mL). Show your work, then give one reason the real number could be very different.

Answer: Worked example: 3 mL collected from 12 leaves gives 0.25 mL per leaf. $20,000 \text{ leaves} \times 0.25 \text{ mL} = 5,000 \text{ mL} = 5 \text{ L}$ in the same hours. The real number could differ a lot because the bag trapped humid air and slowed transpiration (so the real rate per leaf is probably higher), because leaves deep in the tree's shade transpire less than sunlit ones, and because leaf size and species vary enormously.

Why: Check the mL per leaf step and the mL to L conversion. The estimate is meant to show that a tree moves liters of water a day, not to give a precise figure; any sound reason for the difference earns credit.

Also acceptable: Accept any correct scaling from the student's own data; if the sunny bag collected nothing, allow use of the class average.

8. California stores a lot of its water in open reservoirs in the hot Central Valley. Using your tray data, explain what happens to some of that stored water every summer day and why a reservoir in a cool, shaded mountain canyon would lose less. What could a water manager do about it?

Answer: Every summer day, sunlight warms the reservoir's surface and the fastest surface molecules escape as vapor, so part of the stored water leaves without ever being used; the tray in sun lost water at roughly twice the shaded rate, and a reservoir in the hot, sunny valley loses more per square meter than one in a cool, shaded canyon where less energy reaches the surface and the air is cooler. Managers can reduce the loss by storing water in deeper, smaller-surface reservoirs, by keeping it in the cool mountains longer, by storing it underground as groundwater (recharging aquifers), or by covering or shading smaller storage ponds.

Why: Transfer of the sun-shade result to a real resource decision; underground storage is the answer that links to the groundwater content and to Lesson 19.

- Explains the loss as evaporation driven by sunlight, citing the tray data
- Explains why a cool, shaded reservoir loses less
- Proposes at least one reasonable management response

9. Choose the best piece of evidence from your evidence walk. Explain which process it shows, what powered that process, and what you would measure to turn your observation into data.

Answer: Example: damp soil on the north side of the building and dry soil in the sun shows evaporation driven by sunlight (and, where the damp patch is below a spout, runoff and infiltration driven by gravity). To turn it into data, weigh equal scoops of soil from each side before and after air-drying them on a tray for several days, or push a wooden skewer into each and measure how deep the dark, damp zone reaches. Any observation earns credit if the process, driver and a measurable quantity are named.

Why: The question checks that the student can move from noticing to measuring, which is the field-investigation practice.

- Names a real observation and the process it shows
- Names the driver correctly
- Proposes something measurable

Individual evidence of learning

Each student submits their own completed tables, site map, evidence walk table and answers to q1 through q9. The tray and bag tables with the rate calculations in q3 are the primary evidence for the investigation; q4 and q5 are the evidence for understanding transpiration and evaporation as particle-level processes driven by sunlight.

Assessment criteria

Criterion	Proficient looks like
Data collection and calculation	Both trays and all three bags recorded with times; depth lost, mm per hour, mL per leaf and the sun-to-shade ratio computed correctly with units.
Mechanism	Explains evaporation and transpiration with the particle model, places the change of state correctly (inside the leaf for transpiration), and attributes the faster rates in sun to energy from sunlight.

Use of the control and of class data	Uses the leafless bag to rule out other water sources and uses the class table to judge how reliable the sun-shade difference is.
Transfer	Applies the evaporation result to reservoir storage (q8) and turns a field observation into a measurable question (q9).

Accessibility adaptations

- Give students who cannot go outside the indoor version: a tray on a sunny windowsill and one on a shaded shelf, and a bagged branch of a classroom plant in the window and one away from it. The comparison is the same.
- Provide a measurement template with the formulas filled in (depth lost ÷ hours; mL ÷ leaves) and a calculator for q3 and q7.
- Allow the site map to be a labeled photo taken on a phone or tablet, and the evidence walk to be recorded as voice notes transcribed later.
- Pair the Tray technician with a partner for the ruler reading, and let the Recorder role be done on a device with large text.
- Provide a bilingual card for evaporation, transpiration, condensation, control, sun and shade.

Low-cost alternative

Use disposable aluminum pie pans or plastic lids for trays, sandwich bags on smaller twigs, and measure collected water by counting drops into a spoon (about 20 drops per mL). If there is no safe plant access, run the trays only and show the transpiration bag as a teacher demonstration on a classroom plant.

Model limitations

A tray is not a lake and a bagged branch is not a forest: the tray is small, shallow and warms faster than a deep body of water, and the bag traps humid air around the leaves, which slows transpiration below the open-air rate, so the mL per leaf is an underestimate. Sun and shade also differ in temperature and wind, not only in light, so the comparison shows that sunlight matters but cannot separate light from the warmth it causes. One day's data in one yard cannot stand in for a season or a region. This activity has not been physically tested by the authors; the depth losses and bag volumes described are estimates for a warm, clear day, and the teacher's own trial run is the real guide to what to expect.

Teacher notes

Grade q3 and q7 against the group's own recorded numbers; the worked examples are for checking method, not values. In q4, watch for the textbook's version in which liquid water leaves the stomata and then evaporates; the accurate version has evaporation inside the leaf. If weather wrecked a tray, let the group use the class average and say so. Keep the class table; W5 can use it as real data, which is more valuable than any simulated set.