

Who Turned Miller Pond Green? An Evidence Jigsaw

Learning target: I can work with a team to sort evidence, build a model of how nitrogen moved from a field into a pond's living things, and argue from data which source caused the bloom and the fish kill.

Collaborative investigation

About 50 min

Jigsaw

MS-LS2-3 · practice

MS-LS2-4 · practice

collaboration

discussion

data analysis

Standards connections

MS-LS2-3 (practice): The group task is to build a flow model that follows nitrogen from a fertilizer bag through water into algae, decomposers and back, with each arrow backed by an evidence card. It builds the modeling practice of the PE at the scale of one pond.

MS-LS2-4 (practice): Students argue from measurements (nitrate, oxygen, algae cover, fish deaths) that a change to a nonliving component affected populations. The argument is built collaboratively from cards, so it is practice toward the PE rather than individual evidence of meeting it.

Purpose: practice · **Time:** about 50 minutes · **Format:** jigsaw

Answers with reasoning

Twelve evidence cards (teaching scenario)

1 Card 1: The map

Miller Pond is fed by two creeks. North Creek runs along the edge of a six-hectare cornfield before entering the pond. West Creek runs through a cattle pasture before entering the pond. The farmhouse, with its septic tank, sits 80 m from the pond's south shore. A single outlet stream drains the pond.

2 Card 2: The fertilizer log

April 20: 180 kg of nitrate fertilizer spread on the cornfield. The farm's notes say the forecast that day called for heavy rain within the week. No fertilizer has been applied to the pasture this year.

3 Card 3: The rain gauge

April 1 to May 2: 9 mm of rain in total. May 3 to May 5: 62 mm of rain in three days. May 6 to June 3: 4 mm.

4 Card 4: Nitrate in the water (mg/L)

North Creek: April 25, 0.2; May 6, 7.4; May 20, 1.1; June 3, 0.4. West Creek: April 25, 0.9; May 6, 1.4; May 20, 1.0; June 3, 0.9. Pond: April 25, 0.3; May 6, 4.8; May 20, 1.6; June 3, 0.5.

5 Card 5: Algae cover

Percent of the pond surface covered by green scum, estimated from photographs: April 25, 3 percent; May 12, 15 percent; May 24, 70 percent; June 3, 85 percent. Under the microscope the scum is single-celled green algae, a producer.

6 Card 6: Dissolved oxygen (mg/L)

May 30, 5:30 a.m. (dawn): 2.1. May 30, 3:00 p.m.: 11.8. May 31, 5:30 a.m.: 1.8. For comparison, the pond read 7.9 at dawn on April 25. Bluegill need at least about 5 mg/L to stay healthy.

7 Card 7: The fish

May 30, before sunrise: fourteen dead bluegill floating near the north shore; several live fish gulping at the surface. May 31: nine more dead. No dead fish on April 25 or May 12.

8 Card 8: The pasture

Thirty cattle have grazed the West Creek pasture year-round for six years. Their manure contains nitrogen, mostly as ammonium and organic matter, which sticks to soil and is released slowly. West Creek has read about 1 mg/L of nitrate every spring on record.

9 Card 9: The septic test

On May 15 a technician flushed a harmless dye into the farmhouse septic system and watched the pond's south shore for three days. No dye appeared. A sample from the south shore on May 15 read 1.5 mg/L nitrate, lower than the north shore's 2.2 mg/L that day.

10 Card 10: How algae grow

Algae are producers. They build their bodies from carbon dioxide dissolved in the water, water, and dissolved nutrients, using sunlight. The nutrient most often in short supply in this pond is fixed nitrogen (nitrate and ammonium). When fixed nitrogen rises, algae can double their numbers in a day or two.

11 Card 11: What happens when algae die

Dead algae sink. Bacteria feed on them and break them down, using oxygen through cellular respiration. Decomposition is fastest in warm water. Living algae also use oxygen all night; they make oxygen only when there is light.

12 Card 12: Nitrate versus ammonium

Nitrate dissolves completely in water and does not stick to soil particles, so rain can carry it off a field within hours. Ammonium clings to soil and is released over weeks or months. Nitrate fertilizer spread just before a storm is at high risk of washing away.

Part A: Expert round (one set per person)

1. Your expert set: _____. For each of your three cards, write one sentence: 'Card __ proves _____ but does not prove _____.' Be strict: a card proves only what it measures or states.

Answer: Examples. Set A: Card 1 proves North Creek passes the cornfield and West Creek passes the pasture but does not prove which creek carried nitrogen; Card 2 proves 180 kg of nitrate fertilizer was spread before a forecast storm but not that it reached the pond; Card 3 proves a large storm fell May 3-5 after a dry month but not that it carried anything. Set B: Card 4 proves North Creek's nitrate jumped from 0.2 to 7.4 mg/L and the pond's from 0.3 to 4.8 on May 6 while West Creek barely changed, but not what the nitrate did in the pond; Card 5 proves algae cover rose from 3 to 85 percent but not what caused the rise; Card 6 proves dawn oxygen fell to about 2 mg/L in late May but not why. Set C: Card 7 proves fish died at dawn on May 30 and 31 but not the cause; Card 8 proves the pasture adds a steady, low nitrogen input but not that it is harmless; Card 9 proves the septic system is not leaking into the pond but not the source of the north-shore nitrate. Set D: Cards 10, 11 and 12 state how algae grow, how decomposition uses oxygen, and how nitrate moves, but they are general science, not measurements from this pond.

Why: The expert round trains the distinction between a measurement and an inference. Each sentence should state a limit.

Also acceptable: Any accurate limit earns credit; the limits above are examples.

- Set identified
- Three sentences, one per card
- Each sentence names something the card does not prove

Part B: Home group task

1. Each expert teaches their three cards in two minutes. Listeners write the card number next to any step of the story it supports.
2. On a large sheet, draw a flow model that follows nitrogen from the fertilizer bag to the dead fish. Use boxes for reservoirs (fertilizer, field soil, creek water, pond water, algae bodies, dead algae, bacteria, pond water again) and arrows for processes (spreading, runoff, uptake by algae, death, decomposition). Write the number of the card that supports each arrow beside it. An arrow with no card is a guess; mark it with a question mark.
3. Add a second, shorter chain for oxygen: what made the oxygen and what used it up, with card numbers.
4. Complete the suspects table. For each suspect, list the card numbers that point toward it and the card numbers that point away from it.
5. Agree on a verdict: which source caused the bloom, and how confident is the group (sure, fairly sure, unsure)? Rank your three strongest cards.
6. Prepare a one-minute explanation of the model and the verdict. Every member must be able to give it and to answer a challenge from the neighboring group.

Group record: the suspects (fill in)

Suspect	Cards pointing toward it	Cards pointing away from it	Verdict for this suspect
Cornfield fertilizer by way of North Creek			
Cattle pasture by way of West Creek			
Farmhouse septic system			
The storm by itself (rain and mud with no added nitrogen)			

2. Group answer: State your verdict and your three strongest cards in order. For the strongest card, explain in one sentence why no other suspect can explain it.

Answer: Verdict: the cornfield fertilizer, carried by storm runoff down North Creek, caused the bloom.

Strongest cards, in order: Card 4 (North Creek's nitrate rose 37-fold on May 6 while West Creek rose only slightly and the pond tracked North Creek), Card 2 with Card 3 (nitrate spread April 20, then 62 mm of rain May 3-5, the only heavy rain of the season), and Card 12 (nitrate does not stick to soil, so rain washes it off). Why no other suspect explains Card 4: the pasture creek did not spike, the septic system is on the south shore and showed no dye, and rain alone contains almost no nitrate, so only the fertilized field on North Creek can account for a 7.4 mg/L reading in that creek on that date.

Why: Card 4 is the decisive card because it localizes the nitrate to North Creek on the right date; Cards 2, 3 and 12 give the mechanism. Groups may reasonably rank Card 2 or Card 12 second or third.

Also acceptable: Accept Card 9 in the top three if the group argues that eliminating the septic suspect was essential.

- Verdict names the cornfield fertilizer via North Creek
- Three cards ranked
- Strongest card defended by ruling out the other suspects

3. Group answer: Write the hardest challenge the neighboring group raised and how you answered it with card numbers.

Answer: Common challenges and card-based replies: 'Maybe the storm's mud alone fed the algae' (Card 4: West Creek also received the storm but did not spike, and Card 10 says the limiting nutrient is fixed nitrogen, not mud). 'The cows add nitrogen too' (Card 8: West Creek has read about 1 mg/L every spring with no bloom; Card 12: manure nitrogen is released slowly). 'The nitrate was already low when the fish died, so nitrate did not kill them' (Cards 5, 6 and 11: the nitrate became algae, the algae died, decomposers used the oxygen). 'How do you know the septic tank is not leaking?' (Card 9: dye test negative, and the south shore read lower than the north shore).

Why: Credit a specific challenge and a reply that cites card numbers; the quality of the reasoning matters more than which challenge was raised.

Also acceptable: Any reasonable challenge with an evidence-based reply earns credit.

- A real challenge recorded
- Reply cites at least one card number

Part C: Individual accountability (complete alone)

4. Explain why the fertilizer did not harm the pond between April 20 and May 2, even though it had already been spread. Use two card numbers.

Answer: Between April 20 and May 2 only 9 mm of rain fell in the whole month (Card 3), so there was no runoff to carry nitrate off the field. Nitrate moves only when water moves it (Card 12). The fertilizer sat in the field soil until the May 3-5 storm; North Creek still read 0.2 mg/L on April 25 (Card 4).

Why: The timing shows that the fertilizer alone was not enough; water had to move it. This is the reservoir-and-route logic of the chapter.

Also acceptable: Accept Card 4's April 25 reading as the second card.

- Cites the dry period (Card 3)
- Explains that nitrate needs runoff to move (Card 12 or Card 4)

5. Using Card 4, calculate how much nitrate the pond lost between May 6 and June 3, and how much North Creek lost over the same dates. Then explain where the pond's lost nitrogen went, using Card 5.

Answer: Pond: $4.8 \text{ mg/L} - 0.5 \text{ mg/L} = 4.3 \text{ mg/L}$ lost. North Creek: $7.4 \text{ mg/L} - 0.4 \text{ mg/L} = 7.0 \text{ mg/L}$ lost (the creek cleared as the field's nitrate was flushed and no more rain came). The pond's lost nitrogen went into the algae: Card 5 shows algae cover rising from 15 percent on May 12 to 85 percent on June 3 while the nitrate fell, so the nitrogen was built into the bodies of the algae (and later into the bacteria that decomposed them).

Why: The subtraction is straightforward; the interpretation must name the algae as the new reservoir, which is the conservation-of-matter point.

Also acceptable: Accept 'the algae took it up' if the student says it became part of the algae. Some nitrogen also left through the outlet; a student who notes this is reasoning well about the open boundary.

6. The fish died at dawn on May 30, almost four weeks after the nitrate arrived and when the nitrate was already low. Using Cards 5, 6 and 11, explain the chain of events that connects nitrate on May 6 to dead fish on May 30, and why dawn was the dangerous hour.

Answer: May 6: nitrate arrives (Card 4). Over the next three weeks the algae use it to multiply from 15 to 70 percent cover (Card 5). As the bloom thickens, algae in the shaded lower layers and older cells die and sink; bacteria decompose them, using oxygen through cellular respiration (Card 11). At the same time the huge mass of living algae uses oxygen all night and makes oxygen only in daylight (Card 11). So by late May the pond's oxygen swings from very high in the afternoon (11.8 mg/L) to very low at dawn (2.1, then 1.8), as Card 6 shows. Dawn is the dangerous hour because oxygen has been used all night by algae and bacteria with none made since sunset; 2 mg/L is below the 5 mg/L bluegill need, so the fish suffocated before sunrise (Card 7). The nitrate was low by then because it had already become algae; the harm came from the decomposition of the bloom, not from the nitrate itself.

Why: Full credit needs the chain in order, the two oxygen users (bacteria and night-time algae), the day-night swing from Card 6, and the explanation of why low nitrate on May 30 does not clear the fertilizer.

Also acceptable: A student who adds that warm late-May water speeds decomposition (Card 11) is giving a stronger answer.

- Chain from nitrate to algae to decomposition in order
- Names oxygen use by decomposers and by algae at night
- Uses Card 6's dawn and afternoon numbers
- Explains why dawn is the minimum

7. The cattle pasture also sends nitrogen toward the pond every year. Using Cards 8 and 12, explain why that nitrogen has never caused a bloom like this one.

Answer: The pasture's nitrogen is in manure as ammonium and organic matter, which cling to soil and are released slowly over weeks or months (Cards 8 and 12). So West Creek carries a small, steady amount, about 1 mg/L every spring, which the pond's algae use up gradually without a bloom. The cornfield's nitrate, by contrast, does not stick to soil, so one storm delivered a large pulse all at once (7.4 mg/L in North Creek), and a pulse is what lets algae double day after day.

Why: The contrast is steady trickle versus sudden pulse, and the chemistry (ammonium binds to soil; nitrate does not) explains it.

Also acceptable: Accept 'the pasture has always been there and the pond was fine' only if the slow-release reason is given.

- Contrasts slow release (pasture) with a sudden pulse (fertilizer)
- Uses the ammonium-sticks, nitrate-washes idea from Card 12 or Card 8

Scoring rubric

Criterion	4 • Exemplary	3 • Proficient	2 • Developing	1 • Beginning
Expert teaching (Part A)	Each expert states precisely what their three cards prove and do not prove, and teaches them to the group in two minutes without reading the cards aloud.	Cards taught accurately; one 'does not prove' limit is missing or vague.	Cards read aloud rather than taught, or a card is over-claimed (for example, Card 2 'proves the fertilizer caused the bloom').	Expert round skipped or cards misdescribed.
The flow model	Reservoirs and labeled process arrows follow nitrogen from fertilizer to algae to decomposers, every arrow carries a card number or a question mark, and the oxygen chain is drawn with cards 6 and 11.	Model complete with card numbers on most arrows; oxygen chain present but thin.	Model is a list of events rather than reservoirs and arrows, or few arrows are tied to cards.	No model, or a model that contradicts the cards.
Verdict and defense	Verdict names the cornfield fertilizer via North Creek, ranks three cards with reasons, rules out each other suspect with specific cards, and every member answers the neighboring group's challenge with evidence.	Correct verdict with ranked cards; one suspect not explicitly ruled out, or the defense given by only some members.	Verdict stated without ranked evidence, or suspects table incomplete.	No verdict, or a verdict unsupported by the cards.
Individual accountability (Part C)	All four Part C answers are accurate, cite card numbers, and show the student can explain the group's reasoning, including the dawn oxygen chain.	Three of four accurate with card citations; one thin or partly incorrect.	Two accurate; others restate the verdict without the chain of reasoning.	Part C mostly blank or inaccurate.

Teacher notes

Print and cut the twelve cards; the four expert sets are deliberately mixed so that no single expert holds the whole case. The scenario is invented but every mechanism is real: nitrate is highly mobile in runoff while

ammonium binds to soil; blooms follow nutrient pulses within weeks in warm water; the dawn oxygen minimum from night-time respiration plus decomposition is the classic cause of fish kills after blooms; a dye test is a standard way to check a septic system. Card 10 says fixed nitrogen is the nutrient most often limiting in this pond; in many lakes phosphorus is the limiting nutrient instead, so if a student asks, say that which nutrient limits growth depends on the water body and that this pond was chosen to be nitrogen-limited. The correct verdict is the cornfield fertilizer via North Creek; the storm is the trigger, not the source. Pair this sheet with Worksheet 1 (the same two-pond story from the farm's point of view), Worksheet 5 (weekly data from a similar pond) and Lab 3's decision about fertilizer practice.

Scaffold offered to students: Cards are evidence, not conclusions

When you teach your cards, say only what each card shows. Card 4 shows that North Creek's nitrate jumped on May 6; it does not say the fertilizer caused it. Card 2 says fertilizer was spread; it does not say any of it reached the pond. The group's job is to connect cards: Card 2 plus Card 3 plus Card 12 plus Card 4 together make the case. If your group gets stuck on the model, start with the three reservoirs you are surest about (fertilizer bag, pond water, algae) and add the arrows between them first.

Extension: Design the test that would settle it

Your verdict rests on a natural experiment that happened once. Design a controlled test the farm could run next spring to confirm or overturn it: name what you would change, what you would keep the same, what you would measure and when, and what result would prove your group wrong. Then explain why a scientist might still prefer the natural experiment's evidence for the question of what actually happened this year.