REAL-LIFE SCIENCE

Fragile Earth

Teacher guide

For the National 3 and National 4 Science workbooks



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Blewis LEARNING

Using the workbooks

The National 3 and National 4 workbooks for **Fragile Earth** are parallel: the same nine topics in the same order, the same contexts, and the same practical in every topic. Topic numbers match, so a mixed class can work together and each learner records the work at their own level.

HOW THE LEVELS DIFFER

N3	follows a given method, uses ready-made tables and graph frames, circles or ticks conclusions and improvements
N4	plans the investigation (variables, prediction, kit, risk, method), repeats readings, works out averages, draws graphs with their own scales, writes conclusions and evaluations

PRACTICAL SAFETY

Every practical has a Stay safe table and a teacher note with hazards, adapted versions and common problems. The Stay safe tables and these notes are a starting point, not a complete risk assessment: the teacher or school must risk assess every practical for their own learners, room and kit before use, following their employer's policies and national guidance (in Scotland, SSERC). Always check learners' care plans and medical information. Activities with flames or microbes are teacher demonstrations, with example results provided.

NO LAB, NO KIT, OR A LEARNER ABSENT

Each practical includes example results so learners can still complete the results, graph, conclusion and evaluation.

EVIDENCE

The practicals give evidence for the experiment and investigation outcome; the learn pages and check-ups give evidence for knowledge and problem solving. The skills tracker at the back of each workbook can be signed off as you go. Always check the latest course documents and your centre's arrangements.

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TEACHER NOTES

Practical 1: Which fuel releases the most heat?

Time	One 50-minute lesson. Each burn takes about 3 to 4 minutes; four fuels with three repeats is a full lesson, so N3 can record single tests while N4 analyses the sample repeats.
Kit	Spirit burners with caps containing ethanol, propanol, butanol and pentanol (labelled), a metal (copper or aluminium) can, clamp stand, thermometer, balance to 0.01 g, 100 cm^3 measuring cylinder, heatproof mat, safety screen, eye protection.
Prep	Check burners are filled to the correct level and wicks trimmed. Keep stock bottles in a store away from the demonstration bench. Have fresh cold water and a spare can so the can cools between tests.
Expected results	Temperature rise increases from ethanol to pentanol (roughly 20 to 28 °C per gram with 100 cm^3 of water). Heat loss is large: measured energy is often a third or less of the true value.
Levels	N3 watches, records start and end temperatures, works out the rise and draws a bar chart on a ready-made frame. N4 plans the fair test the teacher carries out, averages repeat results, draws a bar chart with their own scale and calculates the energy given to the water.

Safety and inclusion

- **Teacher demonstration only.** These fuels are highly flammable. Use a safety screen, eye protection for everyone, good ventilation, and caps on burners when not lit. Use spill-resistant spirit burners. Only the teacher refills them, when cold, away from all flames, at a separate bench.
- Learners watch from a marked distance. Anyone with a breathing condition can sit further back or record from a photo of the readings.
- Follow your school and local authority guidance and your CLEAPSS or SSERC advice on alcohol burners.

Common problems

- **Burning more than 1 g:** weigh with the cap on and stop slightly early; record the actual mass if it differs.
- **Hot can:** a warm can gives a bigger rise next time. Use a cooled or spare can.
- **Soot on the can** reduces heat transfer. Wipe it between tests.

No lab, no time, or a learner absent?

Sample results are given at both levels, so learners can still work out the rises, draw the bar chart, conclude and evaluate.

Assessment link

Evidence for the experiment and investigation outcome of the Fragile Earth unit: recording and presenting results, drawing a conclusion and evaluating (N3), plus planning the investigation (N4).

Answers: Topic 1

Topic 1: Fuels and energy (N3)

1 What is a fuel?

1 Coal, oil and gas.

2 plants and sea creatures; millions of years.

3 They take millions of years to form, and we are using them much faster than they can be made.

2 Burning fuels

1 Fuel, oxygen and heat.

2 The blanket stops oxygen getting to the fire.

3 gas + **oxygen** → **carbon dioxide** + water

4 Heat and light.

3 Problems with fossil fuels

1 Any two: trees, lochs and the fish in them, stone buildings and statues.

2 carbon dioxide

3 e.g. walk, cycle or take the bus; turn the heating down a little; switch off lights and devices; better insulation.

Practical 1: Which fuel gives out the most heat?

Risk controls, e.g.: fuels: teacher only, behind a safety screen, caps on burners; hot water: do not touch the can, let it cool, keep away from the edge of the bench.

Sample rises: ethanol 21 °C, propanol 24 °C, butanol 26 °C, pentanol 27 °C.

Bar chart: four bars with heights 21, 24, 26 and 27 °C.

Conclusion: pentanol; more. Why: better.

Improvement: repeats give a more reliable average; a lid keeps more heat in the water so the result is more accurate; the same amount of water is needed for a fair test, so the third idea would make it worse.

Check-up

1 Something we burn to release energy (heat and light). 2 coal, gas, oil

3 fuel + **oxygen** → carbon dioxide + **water** 4 Carbon dioxide

5 e.g. damages trees, makes lochs acidic and harms fish, wears away stone buildings.

Topic 1: Fuels and energy (N4)

1 What is a fuel?

1 There is a fixed amount. They take millions of years to form, but we are using them far faster, so they will run out (non-renewable).

2 Coal formed from plants in ancient swamps; oil formed from tiny sea creatures buried on the sea bed.

3 Any two, e.g. petrol (cars), diesel (lorries, buses, tractors), heating oil (home heating), jet fuel or kerosene (aircraft), gas for cooking (bottled gas).

2 Burning fuels

1 methane + oxygen → carbon dioxide + water

2 Fire needs fuel, heat and oxygen. The blanket stops oxygen reaching the fuel, so one side of the triangle is removed and the fire goes out.

3 Burn the candle under a beaker or funnel and draw the gases through limewater (or shake the gas from the beaker with limewater). The limewater turns cloudy (milky).

4 It has no colour or smell, so you cannot tell it is there; it stops the blood carrying oxygen. Stay safe: carbon monoxide alarm, have boilers and fires serviced, keep vents and flues clear.

3 Problems with fossil fuels

1 Coal contains sulfur. When it burns, sulfur dioxide is made. This acid gas rises and dissolves in water in the clouds, falling as acid rain.

2 Benefit, e.g. energy supply, jobs, money for the economy. Problem, e.g. supplies running out, carbon dioxide adds to climate change, risk of oil spills.

Practical 1: Which fuel releases the most heat?

Variables: change the type of fuel; measure the temperature rise of the water (°C); keep the same: volume of water (100 cm^3), mass of fuel burned (1 g), the same can, distance from flame to can, starting temperature.

Prediction, e.g. pentanol will release the most heat because it has the biggest molecules (accept any sensible reasoned prediction).

Equipment: spirit burners, metal can, thermometer, balance, measuring cylinder. Not needed: solar cell, magnet.

Hazards, e.g. hot water and can (do not touch, allow to cool, clamp securely); breathing fumes (good ventilation); eye injury from spitting fuel or splashes (eye protection, stand back).

Method key points: 100 cm^3 of cold water measured with a cylinder; start temperature; weigh burner; burn until 1 g used (reweigh); stir; cap burner; end temperature; rise = end – start; repeat 3 times per fuel with fresh cold water and a cooled can.

Headings: Fuel, Rise 1 (°C), Rise 2 (°C), Rise 3 (°C), Average rise (°C).

Sample averages: ethanol (21 + 19 + 23) ÷ 3 = 21 °C; propanol 24 °C; butanol 26 °C; pentanol 27 °C.

Bar chart: fuel on the x axis, average temperature rise (°C) on the y axis, equal-width bars with gaps.

Conclusion: pentanol released the most heat per gram (27 °C rise) and ethanol the least (21 °C).

Explain: (a) 100 × 4.2 × 21 = 8820 J. (b) Much of the heat is lost to the air and to heating the can and the burner; some fuel may not burn completely.

Evaluate: (a) to check the results are consistent and to find a more reliable average. (b) e.g. use a lid or insulate the can, shield from draughts, keep the flame the same distance from the can, use a more precise thermometer or balance.

Check-up

1 Tiny sea creatures died and sank into mud on the sea bed; they were buried under layers of sediment; over millions of years heat and pressure turned them into crude oil.

2 hydrocarbon + **oxygen** → **carbon dioxide** + **water**

3 Sulfur dioxide and nitrogen oxides. Effect, e.g. damages trees, acidifies lochs and kills fish, wears away stone buildings.

4 Burning fossil fuels releases carbon dioxide, a greenhouse gas. More of it traps more heat in the atmosphere, causing global warming and climate change.

5 (24 + 22 + 26) ÷ 3 = 72 ÷ 3 = 24 °C

TEACHER NOTES

Practical 2: Solar cells and distance

Time	One 50-minute lesson in pairs or threes. N4 repeats at five distances takes about 20 minutes once set up.
Kit per group	Small solar cell (about 0.5 to 3 V), voltmeter or multimeter on the 20 V DC range, two leads, desk lamp or ray box, metre stick. Blinds or blackout if possible. Optional: a small motor to show the effect.
Prep	Test each cell with a lamp at 10 cm to choose a meter range. An LED lamp stays cooler than a filament or halogen lamp. A card tube around the gap cuts out room light if the room cannot be darkened.
Expected results	The voltage falls as the distance increases, steeply at first and then more slowly. Values depend on the cell and lamp; the trend is what matters. Current falls much more sharply than voltage if you use an ammeter instead.
Levels	N3 follows the given method, records one reading at each distance and draws a line graph on a ready-made frame. N4 plans the test, takes three readings at each distance, averages to 2 decimal places and draws a graph with their own scales.

Safety and inclusion

- Lamps get hot: no touching, switch off and allow to cool before moving. Keep liquids away from mains lamps and check leads are not damaged.
- Learners should not stare into bright lamps.
- All roles can be done seated. A learner who finds the meter hard to read can move the cell or record results.
- Follow your school and local authority guidance on practical work.

Common problems

- **Readings jump about:** room light or shadows from people. Darken the room and keep hands out of the beam.
- **Cell tilted:** the angle changes the reading. Prop it against a block so it faces the lamp each time.
- **No reading:** check the meter is on a DC voltage range and the leads are in the right sockets.

No lab, no time, or a learner absent?

Sample results are given at both levels, so learners can still draw the graph, conclude and evaluate.

Assessment link

Evidence for the experiment and investigation outcome of the Fragile Earth unit: following procedures safely, recording and presenting results, drawing a conclusion and evaluating (N3), plus planning the investigation (N4).

Answers: Topic 2

Topic 2: Renewable energy (N3)

1 Energy that won't run out

1 Renewable: wind, solar, hydro, tidal. Non-renewable: coal, gas, oil.

2 Geothermal.

2 Good points and bad points

1 e.g. it is clean (no carbon dioxide while working), it will not run out, Scotland is windy, no fuel to buy.

2 There is no sunlight at night.

3 hydro, because the fast-flowing burn on a steep hill can turn a turbine (the village is not on the coast and has no hot rocks).

3 From power station to home

1 The National Grid.

2 heat

3 Any two, e.g. switch off lights and devices, use LED bulbs, turn the heating down, insulate the loft, only boil the water you need.

Practical 2: Solar cells and distance

Risk controls, e.g.: hot lamp: do not touch, switch off and let it cool; cables: keep them tidy and away from the edge of the bench.

Expected results: the voltage falls as the distance increases. Sample: 2.4, 2.1, 1.8, 1.6, 1.4 V at 10 to 50 cm.

Line graph: points at those values joined with a line that slopes down.

Conclusion: down. Why: less.

Improvement: repeats give a more reliable average; other lights add extra light and change the readings; the same lamp must be used for a fair test, so the third idea would make it worse.

Check-up

1 It will not run out (it is replaced naturally). 2 wind, solar, hydro

3 e.g. no electricity when the wind is not blowing; some people think turbines spoil the view; noise.

4 Energy (as heat). 5 e.g. switch off lights and computers, close doors and windows when the heating is on, use LED bulbs.

Topic 2: Renewable energy (N4)

1 Energy that won't run out

1 Wind is replaced naturally by the weather, so it will not run out. Gas is a fossil fuel that took millions of years to form; once it is used it cannot be replaced, so it is finite.

2 Wave energy uses the up-and-down motion of waves on the surface of the sea; tidal energy uses the flow of water as the tide comes in and goes out, which is predictable, twice a day.

3 For, e.g. renewable, crops take in carbon dioxide as they grow, can be used in existing engines. Against, e.g. uses farmland and water that could grow food, may raise food prices, still releases carbon dioxide when burned, fertiliser and transport use energy.

2 Comparing renewable sources

1 Wind is unreliable because the wind does not always blow. Hydro can be switched on in seconds whenever it is needed, using stored water, so it can fill the gaps when demand is high or the wind drops.

2 e.g. hydro: the steep, fast burn gives falling water to turn a turbine; it is reliable and can run day and night. Or solar on the roof: little upkeep, no noise, but less output in winter. A good answer links the choice to the village's conditions.

3 From power station to home

1 A high voltage means a smaller current in the cables, so less energy is lost as heat and the transmission is more efficient.

2 100 − 8 = 92, so 92%.

3 6% of 150 = 0.06 × 150 = 9 units lost; 150 − 9 = 141 units reach homes.

Practical 2: Solar cells and distance

Variables: change the distance from the lamp (cm); measure the voltage (V); keep the same: the lamp, the solar cell, the angle of the cell (facing the lamp), the room lighting, the voltmeter.

Prediction, e.g. the further away the cell, the lower the voltage, because less light reaches it.

Equipment: solar cell, lamp, voltmeter, leads, metre stick. Not needed: thermometer, spirit burner.

Hazards, e.g. trailing cables (keep tidy, tape down); water near mains lamp (keep liquids away); bright lamp (do not stare into it).

Method key points: connect the cell to the voltmeter; lamp at 0 cm on the metre stick; measure to the front of the cell; room lights off and blinds closed; readings at 10, 20, 30, 40 and 50 cm; three readings at each distance (move away and back); average.

Headings: Distance (cm), Voltage 1, 2, 3 (V), Average voltage (V).

Sample averages: 2.40, 2.13, 1.84, 1.60, 1.35 V.

Graph: distance (cm) on the x axis, average voltage (V) on the y axis; a smooth curve or line falling as distance increases.

Conclusion: as the distance from the lamp increased, the voltage decreased (from 2.40 V at 10 cm to 1.35 V at 50 cm).

Explain: the light spreads out as it travels, so less light energy reaches the solar cell each second when it is further away.

Evaluate: (a) light from the room also reaches the cell, which would increase the readings and make the test unfair. (b) e.g. more repeats; a darker room or a cardboard shield; clamp the cell so its angle stays the same; use a meter with more decimal places.

Check-up

1 Water stored behind a dam flows downhill through pipes; it turns a turbine, which turns a generator to make electricity.

2 They do not always produce electricity when it is needed (no wind on still days, no sun at night). Reduce it by using a mix of sources, sources that can be switched on quickly (such as hydro), or by storing energy (batteries, pumped storage).

3 The crops can be grown again each year, so the fuel is replaced and will not run out.

4 It lowers the voltage to a safe level for use in homes.

5 (2.10 + 2.16 + 2.13) ÷ 3 = 6.39 ÷ 3 = 2.13 V

TEACHER NOTES

Practical 3: Which metal conducts heat best?

Time	One 50-minute lesson in groups of three. N3 and N4 groups can run the same test side by side.
Kit per group	Four rods of the same length and diameter (copper, aluminium, brass, steel; a conductivity rod set is ideal), a 400 cm^3 or larger beaker, heatproof mat, candle wax or petroleum jelly, drawing pins, stopwatch, thermometer (N4).
Prep	Soften the wax in warm water first. A kettle of hot water (not boiling, about 70 °C) poured by an adult. Use a wide, heavy beaker or a conductivity-rod stand, inside a tray, so the rods cannot tip it over; the tray also catches pins.
Expected results	Copper first, then aluminium, brass and steel (often 5 or 6 minutes). Times depend on rod size and water temperature, but the order is reliable.
Levels	N3 follows the given method, records one time per metal and draws a bar chart on a ready-made frame. N4 plans the test, repeats it, averages and draws a bar chart with their own scale.

Safety and inclusion

- Only an adult handles the kettle and pours hot water. Beakers stay on heatproof mats and are not moved while hot. No flames are needed.
- Rods stay hot for several minutes after the test: no touching until cool. Count pins out and back in.
- All roles can be done seated. A learner who prefers not to be near hot water can time and record.
- Follow your school and local authority guidance on practical work.

Common problems

- **Wax too thick or uneven:** pins fall at random times. Use a small, equal blob at the same height.
- **Water cooling between repeats:** use fresh hot water each time or a water bath.
- **Rods touching each other:** heat passes between them. Spread them round the beaker.

No lab, no time, or a learner absent?

The sample results let learners complete the bar chart, conclusion and evaluation without doing the practical.

Assessment link

Gives evidence for the experiment and investigation outcome: following procedures safely, recording and presenting results, drawing a conclusion and evaluating (N3), plus planning (N4).

Answers: Topic 3

Topic 3: Metals and their properties (N3)

1 What are metals like?

1 Steel spoon, copper pipe, aluminium can.

2 heat; insulator.

3 Any two, e.g. shiny, let heat through, let electricity through, strong, bend without breaking, ring when hit.

2 The right metal for the job

1 Light bike frame: aluminium. Wire in a lamp: copper. Wedding ring: gold.

2 lighter; rust.

3 Steel (or iron), because it is strong and cheap.

3 Alloys and magnets

1 A metal mixed with other things to make it better (for example stronger, or so it does not rust).

2 iron, nickel, cobalt.

3 The steel cans (steel contains iron). Aluminium cans are not picked up.

Practical 3: Which metal lets heat through fastest?

Risk controls, e.g.: do not touch the rods until they have cooled; use a small blob of wax, work over a tray and pick up pins straight away.

Expected results: copper fastest, then aluminium, then brass, with steel slowest. Sample: copper 48 s, aluminium 75 s, brass 150 s, steel 320 s.

Conclusion: copper; best conductor copper, worst steel. Use it: copper.

Improvement: averages of three tests are more reliable; the same amount of wax makes the test fairer; the same water temperature makes the test fair.

Check-up

1 shiny; heat; electricity (heat and electricity in either order).

2 Copper lets electricity through very well and bends easily.

3 Iron and carbon.

4 iron

5 Copper is a good (the best) conductor of heat.

Topic 3: Metals and their properties (N4)

1 Properties of metals

1 Aluminium (2.7 g/cm^3).

2 Density = 90 ÷ 10 = 9.0 g/cm^3, so it is copper.

3 Malleable: can be hammered into shape. Ductile: can be pulled into a wire. Sonorous: rings when hit.

4 Copper is a good conductor of heat so the pan heats the food quickly; plastic and wood are insulators so the handle stays cool enough to hold.

2 Choosing a metal

1 Aluminium has a much lower density, so the plane is lighter and uses less fuel; it also does not corrode.

2 Gold is far too expensive (rare); copper conducts very well and costs much less.

3 Steel, because it is strong and cheap. Stop rust by painting it, coating it with zinc (galvanising) or oiling it.

3 Alloys and magnetic metals

1 Carbon atoms are a different size from iron atoms, so the layers of iron atoms cannot slide over each other easily.

2 Mixing in other metals makes the gold harder, so the ring does not bend or scratch easily (and it costs less).

3 Steel cans contain iron and are attracted to the magnet; aluminium cans are not, so they are left behind.

Practical 3: Which metal conducts heat best?

Variables: change the type of metal; measure the time for the pin to drop (s); keep the same: rod length and thickness, amount and height of wax, starting water temperature and depth.

Prediction, e.g. copper will be the best conductor because copper is used for pan bases.

Equipment: metal rods, beaker, wax, drawing pins, stopwatch, thermometer. Not needed: magnet, balance.

Hazards, e.g. hot rods (leave to cool, do not touch the top ends); pins (count them back in, pick up at once); wax (small amount, work over a tray).

Method key points: same-sized blob of wax at the same height on each rod; adult adds water at a measured temperature (about 70 °C); start the stopwatch as the water goes in; record the time each pin drops; repeat three times with fresh water and cooled rods; average.

Headings: Metal, Time 1, 2, 3 (s), Average time (s).

Sample averages: copper 48 s, aluminium 75 s, brass 150 s, steel 321 s.

Bar chart: metals on the x axis, average time (s) on the y axis with an even scale (e.g. 0 to 350 s), bars of equal width with gaps.

Conclusion: copper was the best conductor of heat (shortest time) and steel the worst; order copper, aluminium, brass, steel.

Explain: (a) heat reached the wax and melted it sooner, so heat travelled along the rod faster. (b) Copper conducts heat quickly to the food; plastic is an insulator so the handle stays cool.

Evaluate: (a) the water is cooler for later repeats or for the slow rods, so less heat goes in and times get longer. (b) e.g. keep the water hot in a water bath at a set temperature; more repeats; measure the wax position with a ruler; use the same mass of wax.

Check-up

1 Malleable: can be hammered or pressed into shape without breaking. Ductile: can be drawn out into a wire.

2 e.g. very good electrical conductor; ductile; does not corrode easily; cheaper than gold or silver.

3 Atoms of different sizes stop the layers of metal atoms sliding over each other.

4 Density = 54 ÷ 20 = 2.7 g/cm^3, so it is aluminium.

5 Iron, nickel and cobalt.

TEACHER NOTES

Practical 4: How much catalyst?

Time	One 50-minute lesson in pairs or threes. Each test takes under a minute, plus washing out.
Kit per group	Eye protection, 250 cm^3 measuring cylinder in a tray, 10 cm^3 measuring cylinder or syringe for the peroxide, 3% (10 volume) hydrogen peroxide, washing-up liquid, dried yeast (N3: spatula) or a yeast mixture (N4: syringe), stopwatch.
Prep	For N4, mix dried yeast with warm water (about 5 g in 50 cm^3) 15 minutes before the lesson and stir before each use. Use 3% peroxide only; dispense it yourself for N3.
Expected results	Foam rises within seconds. More yeast gives more foam after 30 s, levelling off as the peroxide runs out. Readings vary with yeast freshness and temperature, so repeats matter.
Levels	N3 follows the given method with spatula measures and draws a bar chart on a ready-made frame. N4 plans the test, repeats it, averages and draws a line graph with their own scales.

Safety and inclusion

- Eye protection throughout. 3% hydrogen peroxide can irritate eyes and skin: wash splashes off with plenty of water. Do not use stronger solutions.
- Stand cylinders in trays to catch foam; wipe up spills to avoid slips. Wash hands at the end.
- All roles can be done seated. A learner who prefers not to handle liquids can time, read the scale or record.
- Follow your school and local authority guidance on practical work, and check your chemical risk assessment for hydrogen peroxide.

Common problems

- **Yeast settling:** stir the mixture before each test, or results drift.
- **Foam overflows:** use a 250 cm^3 cylinder or reduce the peroxide to 5 cm^3 for every test.
- **Reading the scale:** foam tops are uneven; read the main level at eye height.

No lab, no time, or a learner absent?

The sample results let learners complete the graph, conclusion and evaluation without doing the practical.

Assessment link

Gives evidence for the experiment and investigation outcome: following procedures safely, recording and presenting results, drawing a conclusion and evaluating (N3), plus planning (N4).

Answers: Topic 4

Topic 4: Getting and using metals (N3)

1 Where do metals come from?

1 A rock with a useful metal in it.

2 Mine, crush, separate, extract.

3 pure metal

4 e.g. it leaves a huge hole or heaps of waste rock; it destroys habitats for plants and animals; it changes how the land looks.

2 Metals in your phone

1 Any two of gold, copper, aluminium, lithium, cobalt, rare earth metals.

2 e.g. spoils the land, pollutes rivers, uses lots of energy, unsafe work for miners.

3 Take it to an e-waste recycling point; give it to someone who can reuse it.

3 Catalysts

1 faster; not used up.

2 It changes harmful gases from the engine into less harmful gases.

3 They contain rare, valuable metals (such as platinum) that can be used again.

Practical 4: Does more catalyst make more foam?

Risk controls, e.g.: stand the cylinder in a tray and wipe up spills at once; keep the cylinder in the middle of the bench and do not knock it.

Expected results: more yeast gives more foam in 30 s. Sample: 55, 100, 135, 160 cm^3.

Conclusion: more; faster. Why: catalyst; oxygen.

Improvement: averages of three tests are more reliable; weighing the yeast gives exactly the same amount; the same cylinder keeps the test fair.

Check-up

1 A rock with a useful metal in it.

2 Any two, e.g. spoils the landscape, pollutes rivers, uses energy, harms wildlife, unsafe work.

3 We get the metals back so less needs to be mined; it saves energy; less waste goes to landfill.

4 faster; not used up.

5 There was more foam (it rose higher).

Topic 4: Getting and using metals (N4)

1 From ore to metal

1 Getting a metal out of its ore (separating the metal from the other elements it is joined to).

2 Carbon removes the oxygen from iron oxide (reduction), leaving iron (and making carbon dioxide).

3 Gold is very unreactive so it does not join with other elements; aluminium is reactive so it is always found joined in compounds and is hard to separate.

4 Extracting aluminium needs huge amounts of electricity; hydro power gives a large, cheap, steady (renewable) supply.

2 The cost of mining, and recycling

1 Its generator uses strong magnets made with rare earth metals, which have to be mined.

2 Any two, e.g. saves energy, saves finite ores, less landscape damage and pollution, less waste in landfill, cheaper.

3 5% of 200 MJ = 0.05 × 200 = 10 MJ.

3 Catalysts

1 A substance that speeds up a chemical reaction without being used up.

2 The catalyst is not used up by the reaction, so it keeps working.

3 The metals are rare and expensive and mining them causes damage; recycling recovers them for reuse.

Practical 4: How much catalyst?

Variables: change the volume of yeast mixture (cm^3); measure the reading at the top of the foam after 30 s (cm^3); keep the same: volume and concentration of hydrogen peroxide, washing-up liquid, temperature, cylinder size, time.

Prediction, e.g. the more yeast, the more foam, because there is more catalyst to speed up the reaction.

Equipment: eye protection, measuring cylinder (250 cm^3), syringe, yeast mixture, washing-up liquid, stopwatch. Not needed: magnet.

Hazards, e.g. foam overflowing (use a tray, wipe spills); glass cylinder breaking (keep it upright on the tray, report breakages); yeast mixture spilling (wipe up, wash hands).

Method key points: 10 cm^3 peroxide and 1 drop of washing-up liquid each time; add the yeast with a syringe and start timing; read the top of the foam at eye level after 30 s; wash the cylinder; repeat each volume 3 times; average.

Headings: Yeast mixture (cm^3), Foam 1, 2, 3 (cm^3), Average foam (cm^3).

Sample averages: 1 cm^3 61; 2 cm^3 106; 3 cm^3 141; 4 cm^3 164; 5 cm^3 179 cm^3.

Line graph: volume of yeast mixture (cm^3) on the x axis, average foam (cm^3) on the y axis, smooth curve rising steeply then levelling off.

Conclusion: as the volume of yeast increased, the foam volume after 30 s increased, so the reaction was faster; the increase got smaller at higher volumes.

Explain: (a) the reaction makes oxygen gas, which is trapped as bubbles by the washing-up liquid. (b) the hydrogen peroxide starts to run out (it is the limiting factor), so extra catalyst cannot make much more oxygen.

Evaluate: (a) yeast settles to the bottom, so unstirred mixture would give different amounts of yeast in the same volume. (b) e.g. more repeats; keep the temperature the same with a water bath; read the scale at eye level; use a gas syringe to measure the oxygen more accurately.

Check-up

1 Aluminium is more reactive, so it cannot be extracted by heating with carbon; it needs electricity, which uses much more energy.

2 Environmental, e.g. large amounts of waste rock, polluted water, habitat loss, energy use. Human, e.g. unsafe working conditions, low pay, health problems from dust or chemicals, conflict.

3 e.g. saves energy, saves ores, less mining damage and pollution, less landfill.

4 A substance that speeds up a reaction without being used up. e.g. platinum in catalytic converters; iron in making ammonia.

5 e.g. add more hydrogen peroxide to the used mixture: it foams again, so the catalyst is still working (or filter and dry the yeast and show the mass is the same).

TEACHER NOTES

Practical 5: Water filters

Time	One 50-minute lesson in pairs or threes. N3 compares four filters; N4 tests five or six depths of sand with repeats.
Kit per group	Two-litre plastic bottle with the base cut off (cut and edge-taped in advance), beaker or jar that holds the bottle, cotton wool, washed play sand, small gravel, 100 cm^3 measuring cylinder, ruler, clarity card (printed in the N3 workbook, or six lines of print of shrinking size on card), tray.
Prep	Make a bucket of muddy water from bagged topsoil (or soil from an area not fouled by animals) and tap water; learners cover any cuts; stir before each pour so every group gets the same muddiness. Wash the sand first or the first pour comes out cloudy from the sand itself.
Expected results	Cotton wool alone lets through cloudy water. Gravel helps a little, sand much more, gravel on sand best. Clarity improves with sand depth and levels off after about 6 to 8 cm.
Levels	N3 follows the method, records scores and completes a ready-made bar chart. N4 plans the test, repeats each depth, averages and draws a line graph with their own scales.

Safety and inclusion

- The filtered water is never drunk or tasted, however clear it looks. Wash hands after handling soil and muddy water.
- Tape the cut edges of the bottles. Work over trays and mop spills straight away.
- All roles can be done seated. A learner who finds judging the score difficult can pour, time or record.
- Follow your school and local authority guidance on practical work.

Common problems

- **Cloudy water from clean sand:** rinse the sand well before the lesson.
- **Very slow filtering:** the cotton wool plug is packed too tightly. Loosen it.
- **Unfair test:** the mud settles in the bucket. Stir before every pour.

No lab, no time, or a learner absent?

The sample results let learners complete the graph, conclusion and evaluation without doing the practical.

Assessment link

Gives evidence for the experiment and investigation outcome: following procedures safely, recording and presenting results, concluding and evaluating (N3), plus planning (N4).

Answers: Topic 5

Topic 5: Our water supply (N3)

1 The water cycle

1 A evaporation; B condensation; C precipitation; D collection.

2 sun

2 From the hills to your tap

1 Any two: lochs, reservoirs, rivers, under the ground (boreholes).

2 Screens: catches sticks and leaves. Sand filter: traps tiny bits of dirt. Chlorine: kills germs.

3 Germs in water can make people ill (for example, stomach upsets and diarrhoea).

3 Saving water

1 Shower and bath (50 litres).

2 e.g. shorter showers; turn the tap off while brushing teeth; fix drips; full loads in the washing machine.

3 less

Practical 5: Make a water filter

Risk controls, e.g. cut bottle: the edges are taped or the bottle is cut by an adult, handle carefully; never drink the filtered water, wash hands after.

Expected results: cotton wool only gives the cloudiest water; sand is better than gravel; gravel and sand together give the clearest water. Sample scores 1, 2, 4, 5.

Conclusion: gravel and sand; smaller. Safe to drink: germs; chlorine.

Improvement: repeats give more reliable results; the same volume of water and the same muddiness make it a fair test.

Check-up

1 evaporates; clouds; rain 2 a lake used to store water, often held back by a dam 3 screens, sand filter, add chlorine

4 A filter does not remove germs (or dissolved chemicals), so the water could still make you ill.

5 Any two, e.g. short showers, turn off the tap when brushing teeth, fix drips, full washing loads, use a bowl to wash dishes.

Topic 5: Our water supply (N4)

1 The water cycle

1 A evaporation; B condensation; C precipitation; D collection.

2 The air higher up is colder. Warm water vapour rises and cools there, so it condenses into droplets that form clouds.

2 Treating our water

1 Step 2 settling tank (sedimentation); Step 4 disinfection (chlorine).

2 Most of the mud and solid bits sink first, so the sand filter does not clog up as quickly and can trap the tiny bits that are left.

3 Filtering removes solid bits but not all germs (bacteria and viruses are too small); germs can cause disease, so they must be killed.

4 Advantage, e.g. stores lots of water for dry spells; water settles and is cleaner. Disadvantage, e.g. land and homes are flooded to build it; it changes habitats; it costs a lot; the level falls in dry weather.

3 How much water do we use?

1 40 ÷ 140 × 100 = 28.6% (about 29%).

2 2 min × 6 litres × 2 = 24 litres a day; 24 × 7 = 168 litres saved in a week.

3 5 × 8 = 40 litres for the shower; 80 − 40 = 40 litres saved.

Practical 5: How well does a sand filter work?

Variables: change the depth of sand (cm); measure the clarity score of the filtered water; keep the same: volume of muddy water (100 cm^3), how muddy it is (stir or shake first), type of sand, cotton wool plug, bottle and beaker, the person judging the score.

Prediction, e.g. the deeper the sand, the clearer the water, because there is more sand to trap the bits of dirt.

Equipment: cut bottle, beaker, sand, cotton wool, muddy water, measuring cylinder, clarity card, ruler. Not needed: magnet.

Hazards, e.g. cut edge of bottle (tape the edge, adult cuts it); drinking the water (never drink it, it is not clean of germs, wash hands after).

Method key points: plug the neck with cotton wool; measure the sand depth with a ruler; shake the muddy water and measure 100 cm^3; pour through and collect; stand on the clarity card and record the smallest line read; repeat 3 times per depth with fresh sand; average.

Headings: Depth of sand (cm), Trial 1, 2, 3 (clarity score), Average score.

Sample averages: 0 cm 1.3; 2 cm 2.3; 4 cm 3.7; 6 cm 4.7; 8 cm 5.3; 10 cm 5.7.

Graph: depth of sand (cm) on the x axis, average clarity score on the y axis, points joined with a smooth curve that rises then levels off.

Conclusion: as the depth of sand increased, the water got clearer, but the improvement became smaller for the deepest layers.

Explain: (a) the water passes through more sand, so there are more gaps where small bits can be trapped. (b) Filtering does not remove germs or dissolved substances; the water must be disinfected.

Evaluate: (a) the score is a judgement; eyesight and lighting differ. (b) e.g. the same person scores every sample; use the same light; use a light sensor or a phone light meter to measure how much light passes through; more repeats.

Check-up

1 Water vapour cools and turns back into tiny droplets of liquid water (forming clouds).

2 screening, sedimentation, filtration, disinfection

3 To kill harmful germs so the water does not cause disease.

4 4 × 140 = 560 litres a day; 560 × 7 = 3920 litres a week.

5 e.g. treating and pumping water uses energy and chemicals; heating water uses energy; reservoirs run low in dry summers; it saves money; climate change may make dry spells more common.

TEACHER NOTES

Practical 6: Hard and soft water

Time	One 50-minute lesson in pairs. Four samples with one trial (N3) takes about 20 minutes; three trials each (N4) about 40 minutes.
Kit per group	Test tubes and rack, bungs, 10 cm^3 measuring cylinder, dropper, eye protection, about 30 cm^3 each of distilled water, tap water, a mineral water high in calcium, and the same mineral water boiled for 10 minutes and cooled.
Prep	Use **real soap**, not detergent or washing-up liquid (detergents lather even in hard water). Dissolve pure soap flakes in warm distilled water, or use a plain liquid soap. If tap water is very soft, make a hard sample by dissolving a little magnesium sulfate (Epsom salt) in distilled water.
Expected results	Distilled water lathers with 1 to 3 drops. Most Scottish tap water is soft and lathers quickly. Hard mineral water needs many more drops; boiled mineral water needs fewer (some hardness is removed by boiling).
Levels	N3 follows the method, records one count per sample and completes a ready-made bar chart. N4 plans the test, repeats, averages and draws a bar chart with their own scale.

Safety and inclusion

- Eye protection: soap stings the eyes. Learners shake with a thumb firmly on the bung, tube pointing away from faces.
- No tasting any of the samples. Boil the mineral water in advance and let it cool fully.
- Plastic test tubes or small screw-top bottles can replace glass. All roles can be done seated; a learner can count drops while a partner shakes.
- Follow your school and local authority guidance on practical work.

Common problems

- **Everything lathers at once:** the soap is a detergent. Use real soap.
- **Different drop sizes:** hold the dropper upright and use the same one throughout.
- **Lather judged differently:** agree a rule first, such as at least 1 cm of foam lasting 30 seconds.

No lab, no time, or a learner absent?

The sample results let learners complete the graph, conclusion and evaluation without doing the practical.

Assessment link

Gives evidence for the experiment and investigation outcome: following procedures safely, recording and presenting results, concluding and evaluating (N3), plus planning (N4).

Answers: Topic 6

Topic 6: Clean water for everyone (N3)

1 Water around the world

1 1 in 4

2 It can carry germs that cause illnesses such as diarrhoea and cholera.

3 Farming (growing food).

2 Making water safe to drink

1 Filtering: removes bits of dirt. Boiling: kills germs. Desalination: takes salt out of sea water.

2 No; germs.

3 Boil it on the stove (then let it cool). They could filter it through a cloth first to remove bits.

3 Hard and soft water

1 hard; limescale

2 Most of Scotland's rocks, such as granite, do not dissolve easily, so the water picks up very few minerals.

Practical 6: Is it hard or soft?

Risk controls, e.g. soap splashes: wear eye protection, bung in firmly; spills: mop up straight away.

Expected results: distilled water lathers with very few drops; Scottish tap water is usually soft; mineral water needs the most drops; boiled mineral water needs fewer drops than unboiled. Sample results 2, 4, 17, 11.

Conclusion: mineral; most. Tap water: soft (for most of Scotland). Boiling: softer; fewer.

Improvement: repeats give more reliable results; shaking the same number of times and using the same dropper keep the test fair.

Check-up

1 e.g. cholera, typhoid, diarrhoea 2 e.g. boiling, chlorine tablets, filtering and then boiling, leaving clear bottles in strong sunlight, distillation 3 desalination

4 more 5 Limescale; hard water.

Topic 6: Clean water for everyone (N4)

1 Water around the world

1 Sewage contains germs from people's waste; if it gets into a river used for drinking, people swallow the germs and catch diseases such as cholera or diarrhoea.

2 5 × 20 = 100 litres a day, which is 100 ÷ 20 = 5 trips a day; 5 × 7 = 35 trips a week.

3 e.g. less time fetching water, so more time at school; fewer illnesses, so fewer days missed; less heavy carrying.

2 Purifying water

1 Only the water turns to steam at 100 °C; the salt does not evaporate; the steam is cooled in the condenser and turns back into pure liquid water, while the salt stays in the flask.

2 Sailing boat: distillation (or desalination), because it removes the salt; the stove supplies the heat. Sunny village: solar disinfection (sunlight in clear bottles), because the water is already clear and the sunshine is free; boiling or chlorine tablets also acceptable with a reason.

3 Hard and soft water

1 Limescale is a layer that the heater has to warm up as well as the water, and it slows heat getting into the water, so more energy (electricity) is used.

2 Advantage, e.g. contains calcium; many people like the taste. Disadvantage, e.g. limescale in kettles, boilers and pipes; wastes energy; more soap needed; scum.

Practical 6: How hard is the water?

Variables: change the type of water sample; measure the number of drops of soap solution needed for a lasting lather; keep the same: volume of water (10 cm^3), number of shakes, size of drops (same dropper), soap solution, how long the lather must last, temperature of the samples.

Prediction, e.g. the mineral water will be hardest because it has flowed through rocks and has many dissolved minerals.

Equipment: test tubes, rack, bungs, measuring cylinder, dropper, soap solution, eye protection. Not needed: sand, magnet.

Hazards, e.g. soap splashing into eyes (eye protection, firm bung); spills (mop up); glass (rack, report breakages).

Method key points: 10 cm^3 of sample measured with a cylinder; one drop of soap at a time; bung and shake 10 times; lasting lather means at least 1 cm of foam for 30 seconds; count the drops; rinse the tube; repeat 3 times per sample; average.

Headings: Water sample, Trial 1, 2, 3 (drops), Average (drops).

Sample averages: distilled 2.3; tap 4.3; mineral 17; boiled mineral 11 drops.

Bar chart: water samples on the x axis, average drops on the y axis with an even scale, separate bars.

Conclusion: the hardest water was the mineral water, which needed the most drops of soap (17); distilled water was softest.

Explain: (a) distilled water has no dissolved minerals, so nothing reacts with the soap to form scum. (b) Boiling removed some of the hardness, so part of the hardness is the kind that can be removed by boiling (the rest remains).

Evaluate: (a) e.g. measure the height of the lather with a ruler and set a minimum height; time it with a stopwatch. (b) e.g. more repeats; use a burette or the same dropper so drops are the same size; keep samples at the same temperature.

Check-up

1 An illness caused by germs carried in dirty water, e.g. cholera, typhoid.

2 Filtering removes solid bits but germs are too small to be trapped, so they are still in the water.

3 Advantage, e.g. gives fresh water where there is little rain; the sea is a huge supply. Disadvantage, e.g. needs a lot of energy; expensive; the very salty waste water can harm sea life.

4 Limestone dissolves slowly in rain water, adding calcium and magnesium compounds to the water; granite hardly dissolves, so very little is added.

5 Farming; e.g. drip irrigation, watering at night, growing crops suited to the climate, collecting rain water, reducing food waste.

TEACHER NOTES

Practical 7: Temperature and germination

Time	20 minutes to set up, then 15 minutes three days later to count and record. The analysis fits in the second lesson. Start on a Monday or Tuesday so the count does not fall on a weekend.
Kit	Petri dishes or small trays, cotton wool or paper towel, food-grade cress seeds, pipettes, labels, a fridge not used for food or drink, a warm place at about 25 °C (an incubator, not on a radiator), thermometers. Magnifying glasses help learners spot small roots.
Expected results	Very few seeds germinate in the fridge in 3 days. Most germinate at 20 °C and slightly more, or faster, at 25 °C. Above about 35 °C germination falls again, which makes a good extension.
Levels	N3 follows the method with three places, counts germinated seeds and draws a bar chart on a ready-made frame. N4 plans the test, uses three dishes per temperature, works out averages and percentages and draws a line graph with their own scales.

Safety and inclusion

- Use food-grade cress seeds, not seeds treated with fungicide for farming. No eating in the lab. Wash hands after handling seeds.
- Mop up spills straight away. Learners do not need to handle the fridge or incubator themselves.
- All steps can be done seated. Pre-counted seed packets help learners who find fine motor work difficult.
- Follow your school and local authority guidance on practical work.

Common problems

- **Cotton wool dries out** in the warm place: check daily and add the same few drops to every dish.
- **Flooded dishes:** seeds under water lack oxygen and germinate poorly. Damp, not wet.
- **Deciding what counts:** agree in advance that a seed has germinated when a root is visible.

No lab, no time, or a learner absent?

Sample results are given, so learners can still complete the results, graph, conclusion and evaluation.

Assessment link

Evidence for the experiment and investigation outcome: following procedures safely, recording and presenting results, concluding and evaluating (N3), plus planning the investigation and processing data (N4).

Answers: Topic 7

Topic 7: How plants grow (N3)

1 Seeds and germination

1 water, warmth, air.

2 The root.

3 No. Seeds need water to germinate, and the bag is dry.

2 Photosynthesis

1 In the leaves.

2 carbon dioxide; oxygen. Light.

3 Any one: plants make food that animals and people eat; plants give out oxygen that we breathe.

3 What plants need

1 The right amount.

2 Shorter (14 cm against 26 cm).

3 Water and minerals.

4 Compost or manure.

Practical 7

Safety controls: do not eat seeds and keep hands away from the mouth; wash hands afterwards; mop up spills straight away.

Sample results: fridge 2, classroom 16, warm place 18. Bar chart with these heights.

Conclusion: fewest; warm.

Why: faster.

Improvement: three dishes in each place gives more reliable results (you can spot an odd dish); a thermometer checks the temperatures really are different. Using different seeds would make the test unfair.

Check-up

1 When a seed starts to grow.

2 water; oxygen.

3 The leaves.

4 Any two: light, water, carbon dioxide (air), warmth, minerals (from soil or fertiliser).

Topic 7: How plants grow (N4)

1 Seeds and germination

1 A no (no water); B yes; C no, or very few (too cold); D no (no oxygen).

2 Boiling removes the oxygen dissolved in the water, and the oil stops more oxygen getting back in, so it tests whether seeds need oxygen.

3 The seed has a food store. The seedling uses this food (through respiration) for energy until its leaves can photosynthesise.

2 Photosynthesis

1 Carbon dioxide, from the air (through holes in the leaves); water, from the soil (taken in by the roots).

2 Chlorophyll traps (absorbs) light energy for photosynthesis.

3 With no light it cannot photosynthesise, so it cannot make glucose. It uses up its stored food and then cannot release energy or grow.

3 What plants need

1 Growth increases with fertiliser up to the right amount (26 cm), but far too much fertiliser reduces growth (14 cm), only a little more than none (12 cm).

2 26 − 12 = 14 cm taller.

3 Nitrogen (nitrate). Add a fertiliser containing nitrogen, or compost or manure.

4 The minerals make algae grow quickly. The algae block light and, when they die and rot, bacteria use up the oxygen in the water, so fish and other animals can die.

Practical 7

Change: temperature (°C). Measure: number of seeds germinated after 3 days (out of 20). Keep the same: type and number of seeds, amount of water, type of dish and cotton wool, time before counting, light conditions.

Prediction e.g. more seeds will germinate at higher temperatures because warmth speeds up the reactions in the seed.

Kit: dishes, cotton wool, cress seeds, pipette, science fridge (plus thermometers, a warm place). Not needed: balance, sugar.

Hazards e.g. spilled water (slips: mop up); glass dishes (cuts: handle with care, report breakages); seeds swallowed (do not eat anything in the lab).

Headings: Temperature (°C), Dish 1, Dish 2, Dish 3 (seeds germinated), Average, Percentage (%).

Sample results: 5 °C average 2, 10%; 10 °C average 9, 45%; 20 °C average 17, 85%; 25 °C average 18, 90%.

Graph: temperature on the x axis, percentage germinated on the y axis; the line rises steeply then levels off.

Conclusion: as the temperature increased, more seeds germinated, rising quickly up to 20 °C and then levelling off.

Explain: warmth speeds up the reactions (enzymes) in the seed, so the food store is used and growth starts sooner; in the cold these reactions are very slow.

Evaluate a: repeats show whether results are consistent, make it easier to spot an odd result, and give a more reliable average.

Evaluate b: e.g. use more seeds per dish; measure the temperature in each place with a thermometer; add exactly the same volume of water each day; include more temperatures (e.g. 15 °C and 30 °C).

Check-up

1 Water, warmth, oxygen.

2 carbon dioxide + water → glucose + oxygen.

3 From light (sunlight); chlorophyll traps it.

4 Any two: respiration (energy), stored as starch, growth (making new cells, e.g. cellulose).

5 Each crop takes minerals out of the soil, so over time the soil runs short; fertiliser puts the minerals back so the crop grows well.

TEACHER NOTES

Practical 8: Sugar and yeast

Time	One 50-minute lesson: 15 minutes to set up, 20 minutes for the yeast to work (use the time for the learn pages), 10 minutes to read and record.
Kit	100 cm³ measuring cylinders (five per group, or plastic ones), dried baker's yeast, caster sugar, balance (0.1 g), spatulas, a water bath or large tub of water at about 40 °C, timer, labels. Warm water at about 40 °C from a kettle mixed with cold, prepared by an adult.
Expected results	Almost no froth with no sugar; froth increases with sugar and levels off at about 3 to 4 g in 20 cm³ as the yeast works at its fastest. Froth volumes of roughly 20 to 35 cm³ are typical. Results vary with the age of the yeast.
Levels	N3 follows the method, subtracts 20 to find the froth volume and draws a bar chart on a ready-made frame. N4 plans the test, repeats each mass three times, averages and draws a line graph with their own scales.

Safety and inclusion

- Water no hotter than about 40 °C; adults fill the water bath. Stand cylinders in a tray so they cannot tip over. Plastic cylinders remove the glass hazard.
- No eating or drinking; wash hands afterwards. Yeast is low hazard but avoid creating dust. The froth can overflow small cylinders: use 100 cm³ ones.
- All steps can be done seated. Pre-weighed sugar in labelled pots helps learners who find weighing difficult.
- Follow your school and local authority guidance on practical work.

Common problems

- **No froth at all:** water too hot (kills the yeast) or yeast out of date. Test a batch beforehand.
- **Reading the froth:** read the top of the froth at eye level and subtract the starting 20 cm³.

No lab, no time, or a learner absent?

Sample results are given, so learners can still complete the results, graph, conclusion and evaluation.

Assessment link

Evidence for the experiment and investigation outcome: following procedures safely, recording and presenting results, concluding and evaluating (N3), plus planning the investigation and processing data (N4).

Answers: Topic 8

Topic 8: Farming and food (N3)

1 Farming in Scotland

1 sheep, cattle, salmon.

2 To give the crops minerals so they grow bigger and give more food.

3 Algae grow in the loch; this can harm fish and other wildlife.

2 Better crops and animals

1 The sheep with the thickest wool.

2 many years.

3 Any one: genes might spread to wild plants; long-term effects are not fully known; some people feel it is not natural.

3 Making food last

1 The cold slows down the microbes that make it go off.

2 Yeast: makes bread rise. Bacteria: makes yoghurt.

3 Carbon dioxide.

Practical 8

Safety controls: adult fills the water bath and keeps the water warm, not hot; mop up spills; stand cylinders in a tray and handle glass carefully, reporting breakages.

Sample results: 0 g 2, 1 g 14, 2 g 24, 3 g 30, 4 g 32 cm^3. Bar chart with these heights.

Conclusion: more; almost no.

Why: food; carbon dioxide.

Improvement: three repeats make the results more reliable; keeping the bath at the same temperature keeps the test fair. Using cold water for some cylinders would make it unfair.

Check-up

1 e.g. crop: barley, potatoes, raspberries; livestock: sheep, cattle, salmon.

2 Good: fewer crops are eaten or damaged by pests, so there is more food. Problem: it can kill useful insects such as bees.

3 Choosing the best animals or plants and breeding from them, over and over, so the young get better.

4 carbon dioxide; rise.

Topic 8: Farming and food (N4)

1 Farming in Scotland

1 Algae grow very fast: 3. Rain washes fertiliser off the field: 1. Bacteria rot the dead algae and use up the oxygen: 4. The minerals reach the loch: 2.

2 Pesticides can kill bees; with fewer bees, fewer flowers are pollinated, so less fruit forms and the yield falls.

3 e.g. use only the amount needed; avoid spreading before heavy rain; leave a strip of grass or hedge beside streams; use manure or compost; test the soil first.

2 Better crops and animals

1 For: A, C, E. Against: B, D, F.

2 It is much faster (one generation), and genes can come from a different species.

3 Choose the cows that give the most milk and breed them with a bull from a high-yield line; keep the young that give the most milk and breed them; repeat over many generations.

3 Making food last

1 e.g. drying: removes water, which microbes need to grow; freezing: the cold slows microbes almost to a stop; heating: kills microbes; salt or sugar: draws water out so microbes cannot grow.

2 glucose → carbon dioxide + alcohol (ethanol).

3 The yeast is warmer, so it respires (ferments) faster and makes carbon dioxide more quickly.

Practical 8

Change: mass of sugar (g). Measure: volume of froth (cm^3) after 20 minutes. Keep the same: mass of yeast, volume and temperature of water, time, size of cylinder, type of sugar.

Prediction e.g. more sugar will make more gas, because the yeast has more food to ferment.

Kit: measuring cylinders, yeast, sugar, balance, water bath, timer. Not needed: cotton wool.

Hazards e.g. glass cylinders breaking (cuts: stand in a tray, handle with care); yeast and sugar (do not eat; wash hands); spills (slips: mop up).

Headings: Sugar (g), Froth 1, 2, 3 (cm^3), Average (cm^3).

Sample averages: 0 g 2, 1 g 14, 2 g 24, 3 g 30, 4 g 32 cm^3.

Graph: sugar mass on the x axis, average froth volume on the y axis; a curve rising steeply then levelling off.

Conclusion: as the mass of sugar increased, the volume of gas increased, quickly at first and then levelling off.

Explain: yeast uses sugar as food in fermentation, making carbon dioxide; more sugar gives more food, so more gas is made.

Evaluate a: the yeast is working as fast as it can; there is more sugar than it can use in 20 minutes, so something else (the amount of yeast or the time) limits the gas made.

Evaluate b: e.g. more repeats; use a water bath with a thermostat; measure the gas with a gas syringe or upturned cylinder instead of froth; mix each cylinder in the same way.

Check-up

1 Fertiliser washes into the loch and makes algae grow quickly; when the algae die, bacteria rot them and use up the oxygen, so fish and other animals die.

2 Selective breeding uses natural breeding over many generations; GM changes the genes directly in one step and can use genes from other species.

3 For e.g. higher yields, crops that resist pests or drought, extra vitamins. Against e.g. genes may spread to wild plants, unknown long-term effects, some people feel it is unnatural.

4 Salt draws water out of the fish and the microbes, so microbes cannot grow and the fish does not spoil.

5 Carbon dioxide; its bubbles make the dough rise so bread is light.

TEACHER NOTES

Practical 9: Temperature and mould

Time	15 minutes to set up, then 5 minutes on days 2, 4 and 6 to score the slices through the bags. Analysis in the final lesson. Avoid setting up just before a weekend or holiday.
Kit	Slices from one loaf (bakery bread without preservative moulds faster), zip-seal bags, clear tape, pipettes and water, marker pens, disposable gloves, a fridge used only for science (never one used for food or drink), a warm place (an incubator at about 25 °C; not on or next to a radiator). Label every bag "Science: do not eat". N4: a 5 × 5 grid drawn on acetate or on the bag.
Expected results	No visible mould in the fridge after 6 days; some at room temperature; the most in the warm place. Bread with preservative may take 7 to 10 days, so extend the test if needed.
Levels	N3 follows the method, uses the mould score picture scale and draws a bar chart on a ready-made frame. N4 plans the test, counts mouldy squares on a grid for three slices per temperature, works out averages and percentages and draws a line graph.

Safety and inclusion

- **Bags are sealed and taped and are never opened.** At the end, an adult puts them, unopened, into a second bag and into the general waste. Do not incubate above 25 °C.
- Learners with asthma or mould allergies observe from a distance or use photographs. Wear gloves when setting up; wash hands afterwards.
- No food is eaten. All steps can be done seated, and scoring can be done from photos taken through the bag.
- Follow your school and local authority guidance on practical work, including your guidance on growing microorganisms.

Common problems

- **No mould in time:** use preservative-free bread and add the water drops; leave the bags in a little longer.
- **Different scores from different learners:** agree the scale first; use the same scorer for every bag.

No lab, no time, or a learner absent?

Sample results are given, so learners can still complete the results, graph, conclusion and evaluation.

Assessment link

Evidence for the experiment and investigation outcome: following procedures safely, recording and presenting results, concluding and evaluating (N3), plus planning the investigation and processing data (N4).

Answers: Topic 9

Topic 9: Feeding the world (N3)

1 Too little, too much

1 A long time with little or no rain.

2 floods, war.

3 Good food is being wasted when it could feed people who need it; the food is not shared out fairly.

2 Food miles and choices

1 The strawberries from Arrin Farm (10 miles).

2 June to August.

3 Any one: fewer food miles, so less fuel is burned; fresher food; it helps local farmers.

3 Food waste

1 Wednesday (15 kg).

2 8 kg.

3 Make a shopping list; freeze leftovers.

Practical 9

Safety controls: never open the bags, and keep away if you have asthma or a mould allergy; mop up water drops straight away.

Sample results (day 6): fridge 0, classroom 3, warm place 5. Bar chart with these heights.

Conclusion: warm place; cold.

Why: faster.

Improvement: more slices in each place make the results more reliable; the same kind of bread keeps the test fair. Opening the bags is not safe.

Check-up

1 Any two: drought, floods or storms, climate change, war or conflict, cost (people cannot afford food), pests or disease.

2 How far food travels from the farm to your plate.

3 use by.

4 e.g. smaller portions with seconds available; let pupils choose their food; compost leftovers; plan menus pupils like; use leftovers in other meals.

Topic 9: Feeding the world (N4)

1 Too little, too much

1 Climate change brings more droughts, floods and extreme heat. Crops fail or are damaged and animals die, so less food is produced in those places.

2 Any two: weather and climate (good farmland and rainfall in some places, drought in others); money (richer countries can afford to farm intensively and to import food); conflict destroys farms and transport; pests and disease; waste and poor storage.

3 e.g. reduce their own food waste; give aid in emergencies; share farming knowledge, seeds and technology; trade fairly; help with water supplies and storage.

2 Food miles and choices

1 1500 − 10 = 1490 miles more.

2 It is grown at its natural time of year, so it needs less energy (no heated greenhouses) and usually travels a shorter distance, so less fuel is burned and less carbon dioxide released.

3 Not always. Local food grown out of season in heated greenhouses can use more energy than food grown outdoors abroad and brought by ship. Food miles are only one part of the picture.

3 Food waste

1 Total = 12 + 9 + 15 + 8 + 11 = 55 kg. Average = 55 ÷ 5 = 11 kg per day.

2 Reduction = 55 − 44 = 11 kg. 11 ÷ 55 × 100 = 20%.

3 e.g. smaller portions with seconds, so less is left on plates; a pre-order system, so the kitchen cooks the right amount; compost unavoidable waste, so less goes to landfill; menus pupils have chosen.

Practical 9

Change: storage temperature (°C). Measure: number of squares (out of 25) with mould on day 6, or percentage covered. Keep the same: type and size of bread (same loaf), number of water drops, bag type, number of days, light.

Prediction e.g. more mould will grow at higher temperatures, because mould is a living fungus that grows faster when it is warm.

Kit: sealable bags, grid sheet, pipette, science fridge, gloves. Not needed: yeast, balance.

Hazards e.g. eating the bread (illness: never open bags, no eating in the lab); water spills (slips: mop up); warm place too hot (burns or fire risk near heaters: use an incubator at about 25 °C, never a radiator).

Headings: Temperature (°C), Slice 1, Slice 2, Slice 3 (mouldy squares), Average, Percentage (%).

Sample results: 5 °C average 0, 0%; 15 °C average 4, 16%; 20 °C average 10, 40%; 25 °C average 16, 64%.

Graph: temperature on the x axis, percentage covered on the y axis; the line rises more steeply at higher temperatures.

Conclusion: as the storage temperature increased, more of the bread was covered in mould.

Explain: mould is a living microbe (fungus); warmth speeds up its growth and reproduction, while cold slows it down almost to a stop.

Evaluate a: bread from different loaves may have different preservatives, freshness or recipes, which would change how fast mould grows, so the test would not be fair.

Evaluate b: e.g. more slices at each temperature; use incubators set to exact temperatures; one person scores all the slices; record every day and plot mould against time.

Check-up

1 A shortage is not enough food for the people in a place; a surplus is more food than is needed.

2 Fighting can destroy farms, crops and stores, stop farmers working their land, and block roads and trade so food cannot reach people.

3 Advantage e.g. a wider choice of foods all year round. Disadvantage e.g. more food miles and carbon dioxide from transport.

4 Use by is about safety: do not eat after it. Best before is about quality: the food is usually still safe to eat after it.

5 2.5 × 52 = 130 kg a year.

About the author

C. Blewis has taught for 17 years, including 10 years in Additional Support Needs (ASN) provision, teaching sciences, maths, PE and more.

In many schools, especially smaller and specialist settings, teachers are often asked to teach outside their own subject. These books are written for them, and for the young people they teach: clear, practical and ready to use from the first lesson.