GAC013 Science II: Scientific Principles

GAC Science

What this module is, and how it is marked

Two paper samples retain different amounts of water. Does that mean one is best for every cleaning task? To answer well, a scientist asks how the comparison was made, which properties were tested and what remains unknown.

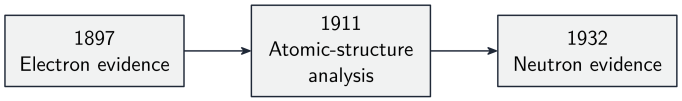
This guide supports GAC013: the development of scientific ideas, investigation, scientific language, the organisation of research and scientific issues. Science includes evidence, methods, explanations and a growing body of knowledge. Its questions connect physics, chemistry, biology and other fields.

A **practical investigation** needs a safe, permitted method that fits its question. An **investigation report** records that method, the actual observations and a conclusion limited by the evidence. Follow your teacher's current brief for assessment criteria, structure and deadlines. The original companion sheets are practice, not official assessment papers. No result or phrase guarantees a mark. Never replace an unexpected observation with a predicted answer.

The history of science

A **paradigm** is a broad framework shaping explanations and questions. A **paradigm shift** is a substantial change in that framework. Not every revised number or new observation is a shift of this scale.

Scientific explanations are **provisional**: they remain open to evidence-led revision. This does not mean that every explanation is equally uncertain. A model represents selected features of a system; observations test how well its predictions and explanations work within a stated scope.



■ **Worked example: separate event dates from award dates**

Thomson identified the electron in 1897. Rutherford's 1911 atomic-structure analysis drew on scattering measurements, including work by Geiger and Marsden. Chadwick established evidence for the neutron in 1932. These are selected developments, not a complete history of science. A scientist's award year is not automatically the discovery or publication year.

Sources checked 2 October 2026: Nobel atomic-history timeline, electron discovery, and Chadwick facts.

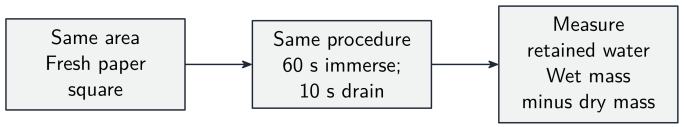
Physics studies matter and energy. Chemistry studies substances and their changes. Biology studies living systems. A plant-growth investigation can be biological while using physical measurements of light and chemical ideas about materials. Naming its main field does not supply its result.

The scientific method

A **hypothesis** is a testable proposed explanation or prediction. Identify what observations would support or challenge it. Research can involve controlled experiments, observation, modelling and revision; it does not always follow one straight sequence.

In a controlled experiment, the **independent variable** is deliberately changed, the **dependent variable** is the measured response, and **control variables** are kept comparable. A **control group** can provide a comparison without the treatment where the design requires it. Comparing two materials is not automatically a treatment-versus-no-treatment design.

Repeat trials to examine variation and reduce dependence on one reading. Repeats do not repair a systematically unequal procedure, and a single careful observation is not automatically worthless. Report what the evidence permits and what further checking would help.



Worked example: controlled conditions and a mean

In the fictional written task, fresh squares of two paper types have the same area. Each is immersed for 60 seconds, drained for 10 seconds without squeezing, and weighed using the same checked balance. Retained-water mass is wet mass minus dry mass. Type A records 3.0, 3.2 and 2.8 grams; B records 4.2, 4.0 and 4.4 grams. The mean summarises the three trials:

$$\bar{m} = \frac{m_1 + m_2 + m_3}{3}$$

$$\bar{m}_A = \frac{3.0 + 3.2 + 2.8}{3} = 3.0 \text{ g}$$

$$\bar{m}_B = \frac{4.2 + 4.0 + 4.4}{3} = 4.2 \text{ g}$$

The difference between means is 1.2 grams. Individual trials vary. Squeezing only A adds another changed condition and undermines a comparison of paper type. Strength, price and other uses were not tested, so "B is always best" is unsupported. Any real practical activity requires the teacher's approved procedure and supervision.

The language of science

Units identify the scale of a physical quantity. Some quantities, such as a count or a ratio, are dimensionless but still need a clear definition. A unit conversion changes representation, not the physical quantity. For area, square the length conversion factor.

Accuracy concerns closeness to a suitable reference or true value. **Precision** concerns closeness of repeated readings. An instrument can give close repeats with a systematic offset. Significant figures help communicate the supported numerical precision; calculator output is not evidence for extra digits.

Uncertainty describes limitations on a measurement or estimate. Instrument resolution, procedure and variation can contribute. Do not invent an uncertainty range or confidence level that was never established.

Worked example: average speed is not constant speed

For the supplied trolley record, travelled distance is 3.60 metres and elapsed time is 48.0 seconds. Average speed is distance per elapsed time:

$$v_{\text{avg}} = \frac{d}{t}$$

$$v_{\text{avg}} = \frac{3.60 \text{ m}}{48.0 \text{ s}} = 0.0750 \ \frac{\text{m}}{\text{s}}$$

This is an interval average, not a speed at every moment. Separately, timer repeats of 10.1, 10.1 and 10.2 seconds are close, but they disagree with a supplied 12.0-second reference. Investigate the timing procedure instead of claiming accuracy from closeness alone.

The organization of science

Peer review asks relevant specialists to examine a study's methods and reasoning. It can identify weaknesses, but is not automatic product certification. **Replication** obtains new observations using an appropriately comparable procedure to investigate a finding. Checking calculations on the same readings is useful, but does not supply a new independent experiment.

Research **institutions** provide people, resources and rules. Disclose funding and relevant interests. Examine whether they affect design, analysis or reporting; funding alone proves neither honesty nor dishonesty. Transparent records and independent scrutiny help readers judge a claim.

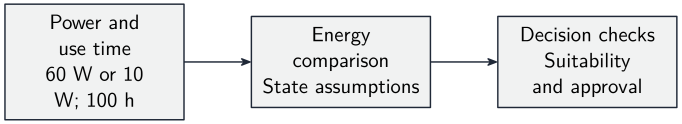
Worked example: a review finds a condition that matters

A fictional insulating-sleeve report compares cups starting at different temperatures. A reviewer flags that difference. A second calculation cannot remove the unequal starting condition. A second school's independent experiment could improve checking, but it supplies no confirmation until performed. Keep the original record and explain its limit rather than inventing a successful replication.

Scientific issues

Scientific work can inform decisions about technologies and their effects. Evidence does not by itself decide every value, cost or acceptable trade-off. A **risk** concerns both the chance and seriousness of harm; a possible harm is not automatically frequent, and uncertainty is not proof of zero risk.

Communicating uncertainty means describing the assumptions, scope and unknowns accurately. Use an established range where available, but do not invent one because a single number looks insufficient. A bounded estimate can still be useful.



■ Worked example: an energy benefit is one decision input

Assume a lamp operates 5 hours daily for 20 days: 100 hours. Compare constant powers of 60 watts and 10 watts. Convert to kilowatts because the requested energy unit is kilowatt-hours:

$$E = Pt$$

$$E_{old} = 0.060 \text{ kW} \times 100 \text{ h} = 6.0 \text{ kWh}$$

$$E_{new} = 0.010 \text{ kW} \times 100 \text{ h} = 1.0 \text{ kWh}$$

The estimated reduction is 5.0 kilowatt-hours under those assumptions. No tariff establishes a monetary saving, and no lighting measurement establishes equal brightness. Check required performance, purchase and installation costs, compatibility and reliability. Replacement needs school approval and authorised personnel. Students should analyse the supplied data, not carry out electrical installation.