

Scientific Principles: Evidence, Measurement and Reports

GAC013 outcome practice; check the current centre brief.

A paper comparison cannot answer every product question

- One paper retains more water in a specified comparison.
- Ask which property was measured and how.
- Strength, price and other uses need further evidence.

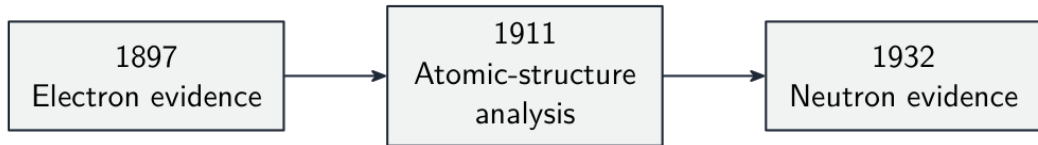
Evidence, methods and the actual assignment brief

- Science includes evidence, methods, explanations and knowledge.
- An investigation uses a safe, permitted method suited to its question.
- A report records actual observations and a bounded conclusion.
- Follow the current centre brief; no phrase guarantees a mark.

Frameworks can change without making every claim equally uncertain

- A paradigm shapes explanations and research questions.
- A paradigm shift substantially changes that framework.
- Provisional explanations remain open to evidence-led revision.
- A revised number alone need not be a paradigm shift.

Selected atomic developments, not an award chronology



- 1897: Thomson identified the electron.
- 1911: Rutherford analysed atomic structure using scattering evidence.
- 1932: Chadwick established neutron evidence.

One investigation can connect several sciences

- Physics studies matter and energy.
- Chemistry studies substances and their changes.
- Biology studies living systems.
- Plant growth can involve light measurements and chemical conditions.

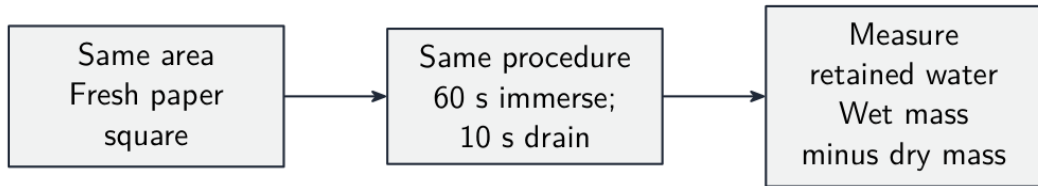
A testable question and more than one research route

- A hypothesis is a testable explanation or prediction.
- Specify observations that could support or challenge it.
- Research can use experiments, observation and modelling.
- Investigation and revision need not follow one straight sequence.

Variables and a meaningful comparison

- Independent variable: the condition deliberately changed.
- Dependent variable: the measured response.
- Control variables: relevant conditions kept comparable.
- A control group is useful where the design requires one.

The paper procedure defines retained water



- Use fresh squares with the same area.
- Immerse for 60 seconds; drain for 10 seconds without squeezing.
- Retained-water mass is wet mass minus dry mass.

Repeats reveal variation, not a repaired procedure

- Repeated trials reduce reliance on one reading.
- They help show how the readings vary.
- Repeating a systematically unequal method preserves its bias.
- A careful single observation can still provide limited evidence.

Calculate each mean and retain the readings

- A readings: 3.0, 3.2, 2.8 grams; mean 3.0 grams.
- B readings: 4.2, 4.0, 4.4 grams; mean 4.2 grams.
- The mean difference is 1.2 grams.
- Individual readings vary; the means do not describe everything.

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

Units explain scale; definitions explain the quantity

- A physical measurement needs an appropriate unit.
- Counts and ratios can be dimensionless but still need definitions.
- A conversion changes representation, not the physical quantity.
- For area, square the length conversion factor.

$$1 \text{ m}^2 = (100 \text{ cm})^2 = 10,000 \text{ cm}^2$$

Accuracy and precision answer different questions

- Accuracy: closeness to a suitable reference or true value.
- Precision: closeness of repeated readings.
- 10.1, 10.1 and 10.2 seconds are close repeats.
- They disagree with a supplied 12.0-second reference.

Supported digits and measurement uncertainty

- Significant figures communicate supported numerical precision.
- Extra calculator digits are not extra evidence.
- Resolution, procedure and variation can contribute to uncertainty.
- Do not invent a range or confidence level.

Distance and elapsed time define an interval average



- The trolley travels 3.60 metres in 48.0 seconds.
- Average speed is distance divided by elapsed time.
- Keep the quantity and units visible.

A speed result does not establish constant motion

- 3.60 divided by 48.0 gives 0.0750 metres per second.
- This is an interval average.
- The supplied record does not establish a constant instantaneous speed.

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

Review, calculation checks and replication have different roles



- Peer review examines methods and reasoning.
- Rechecking a calculation uses the same observations.
- Replication obtains new observations with a comparable method.

An unequal starting temperature limits the sleeve comparison

- The fictional sleeve report starts its cups at different temperatures.
- A reviewer flags that design difference.
- Recalculating cannot remove the unequal condition.
- Keep the record and label the independent test as planned.

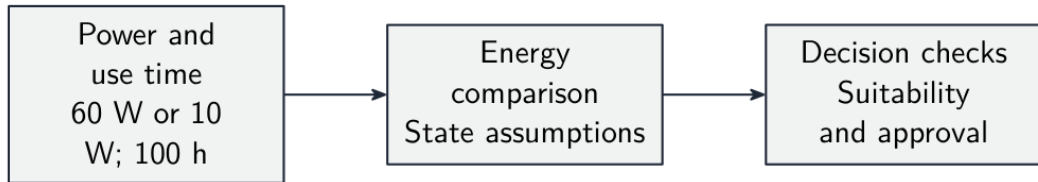
Institutions, funding and transparent records

- Research institutions provide resources, people and rules.
- Disclose funding and relevant interests.
- Examine possible effects on design, analysis and reporting.
- Funding alone establishes neither honesty nor dishonesty.

A decision needs evidence and a view of trade-offs

- Scientific evidence can inform technology decisions.
- Costs, values and acceptable trade-offs also matter.
- Risk involves both chance and seriousness of harm.
- Uncertainty establishes neither certainty of harm nor zero risk.

The lamp diagram begins with assumptions



- Compare constant powers of 60 watts and 10 watts.
- Five hours daily for twenty days gives 100 hours.
- An energy estimate is one input to the decision.

Calculate energy in compatible units

- Convert 60 watts to 0.060 kilowatts.
- Old estimate: $0.060 \text{ kilowatts} \times 100 \text{ hours} = 6.0 \text{ kilowatt-hours}$.
- New estimate: $0.010 \text{ kilowatts} \times 100 \text{ hours} = 1.0 \text{ kilowatt-hour}$.
- Estimated reduction: 5.0 kilowatt-hours.

$$E = Pt, \quad \Delta E = (0.060 - 0.010) \text{ kW} \times 100 \text{ h} = 5.0 \text{ kWh}$$

Energy saving is not every decision requirement

- No tariff has been supplied to calculate a monetary saving.
- No measurement establishes equal brightness.
- Check costs, compatibility, required performance and reliability.
- School approval and authorised personnel govern replacement.

A report connects the conclusion to the recorded method

- The extra notes develop GAC013 investigation reporting.
- Keep the original handout and the report notes together.
- A reader should be able to trace each conclusion to evidence.
- The teacher's current brief sets the required format.

Write the plan before the observations

- Question: which paper retains more water under this procedure?
- Prediction: specify a testable expected comparison.
- Define paper type, wet-minus-dry mass and relevant controls.
- Decide trial order and obtain agreement on the safe method.

Keep dated records of what actually happens

- Record materials, instructions, units, readings and changes.
- Keep unexpected results and flag missing readings.
- Do not invent trials or hide departures from the plan.
- A proposed improvement is separate from a completed trial.

Show raw readings as well as means

- A: 3.0, 3.2, 2.8 grams; B: 4.2, 4.0, 4.4 grams.
- The notes retain all three readings for each paper.
- Each set spans 0.4 grams.
- This spread alone is not the complete measurement uncertainty.

$$\overline{m}_A = 3.0 \text{ g}, \quad \overline{m}_B = 4.2 \text{ g}, \quad \overline{m}_B - \overline{m}_A = 1.2 \text{ g}$$

A conclusion should answer only the question tested

- B retained more water on average under the supplied conditions.
- The mean difference was 1.2 grams; both sets varied.
- Other properties and uses were not tested.
- A limitation explains a specific problem and its effect.

A changed draining time is evidence to record

- One A trial uses a longer draining time.
- Its lower mass may reflect the procedure difference.
- Preserve the original reading and flag the deviation.
- A later agreed trial adds evidence without erasing the event.

Organise the report around evidence

- Question and background: the problem, prediction and relevant ideas.
- Method: materials, variables, procedure, safety and reasons.
- Results: observations, units, tables and checked calculations.
- Discussion: conclusion, alternatives, limits and improvements.

References identify borrowed claims, not independent confirmation

- Identify the sources of borrowed facts, ideas and images.
- Use the required reference style and enough information to locate sources.
- Label supplied data, planned work and completed observations separately.
- Check who produced a source and what evidence it provides.

Check yourself

- Identify paper type and retained-water mass as the two variables.
- Explain why squeezing only A undermines the comparison.
- Calculate the 1.2-gram mean difference and state its scope.
- Explain why a planned independent test has not confirmed the result.