

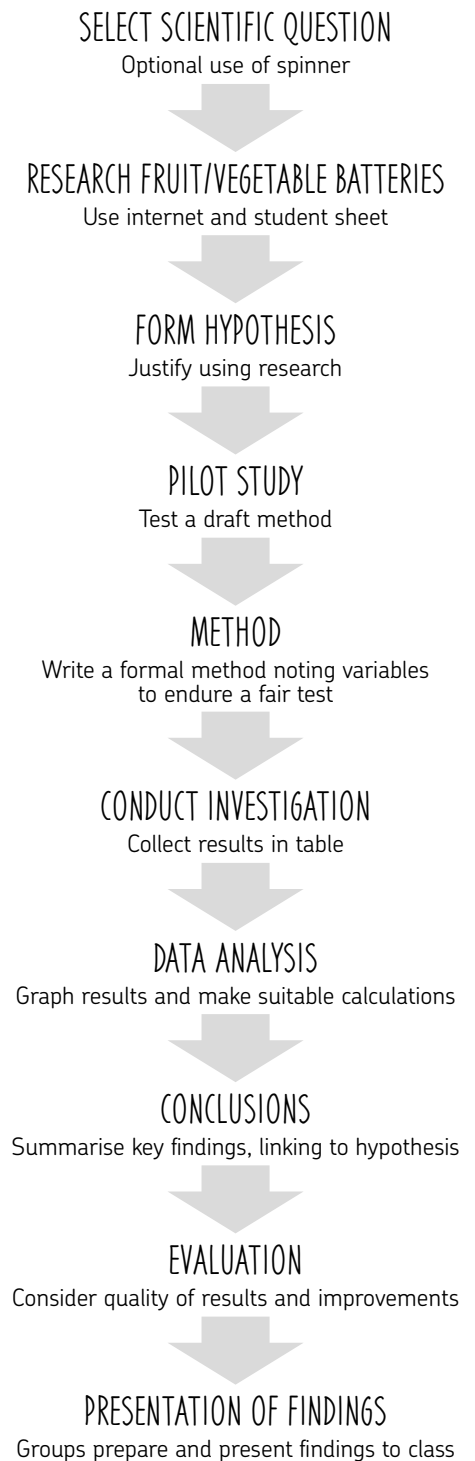
Teachers guidance – Vegetable battery investigation

Scientific Investigations

We suggest that the vegetables batteries are used as the basis of a scientific investigation. A suggested procedure is outlined here (summarised in the diagram), along with some brief notes on how the battery operates. Curriculum links are also detailed. Teachers may prefer to adapt the procedure as they see fit. Ideally students work in small teams throughout.

Suggested questions for investigation:

- Which fruit/vegetable provides the most electricity?
- Which metal combinations provide the most electricity?¹
- Do bigger pieces of fruit/vegetable give you more electricity?
- Do bigger electrodes give you more electricity?
- Which apple/potato varieties provide the most electricity?
- Which supermarket provides the best potatoes for batteries?
- Do apples from Llangefni or Holyhead produce more electricity?



¹ The kits contain strip of different metal that can be directly inserted into the fruit/vegetable. The voltmeter can be used to measure the resultant voltage by clipping it onto the exposed sections of metal. Ignore any minus signs that appear.

Example:

1. A teacher may provide, ask students to identify or use the spinner to select a **scientific question** such as, “Which fruit/vegetable provides the most electricity?”
2. In order to reasonably justify their hypothesis, students should read the “How it works” section of the handout and conduct additional internet **research**. Caution is required when finding sites of appropriate detail and reliable content in reference to fruit batteries.
3. Based on their research, pupils can **form a hypothesis**. A writing frame may be useful for some pupils to help them develop a concise and justified hypothesis. For example

I think that lemons will be the best fruit because they are the most acidic (sour tasting)

4. A **pilot study** helps students to both visualise the method, identify unforeseen problems and consider the variables.
5. Based on their pilot study, pupils can write a formal step by step **method**. This should reference variables and recognise that some must be controlled to ensure a fair test. In this example the variables are:

Independent variable - fruit type;

Dependent variable - voltage;

Control variables - size of fruit chunks, types of metal, electrode insertion depth, size of electrodes.

Students should also outline any risks or hazards as part of their method. They may like to list them in a table as shown below

Example Hazard table entry:

Hazard	Harm	Risk	Risk reduction
Fruit acid	Could enter eye or cut and cause stinging	Low - moderate	Wear goggles. Avoid fruit if have cuts.

6. Students carry out their **investigation** and collect the data in a table, such as the one shown below. Attention must be paid to the correct use of units, decimal points and rounding. Higher ability/older students may be encouraged to take repeat readings and calculate a mean value to ensure their results are repeatable.

Fruit	Reading 1 /V	Reading 2 /V	Reading 3 /V	Mean Voltage / V
Apple	0.88	0.90	0.92	0.90
Banana	0.32	0.28	0.30	0.30
Lemon	1.10	1.10	1.10	1.10
Potato	0.34	0.68	1.52	0.85

7. **Data analysis** involves assessing the tabulated data and producing a graph to help elucidate any patterns. In this example a simple bar chart would offer a good means to display the results and aid analysis. Rather than simply state which gave the most voltage, pupils could be encouraged to consider differences, fractions and proportions. For example, pupils could consider how much more voltage the apple provided compared to the banana (0.6 V more; 3 times as much).
8. **Conclusions** need to be linked back to the hypothesis. Were lemons the best for producing a high voltage? Were they significantly better or marginally? Pupil should refer directly to the data when drawing conclusions.
9. **Evaluations** must consider the quality of results and any improvements that can be made (or were made) to the method. In this example the pupil may consider the potato results unreliable and speculate why this would be and what alternative method may be applied.
10. **Presentation** of results to peers is a key part of the scientific method which is often overlooked. The investigation provides an excellent opportunity for students to practise their presentation skills and further work in groups. It also offers a platform for discussion and comparison of data between groups.

Principles of the Vegetable Battery

When a metal (electrode) is inserted into the acidic juice contained within fruit and vegetables (the electrolyte), a chemical reaction takes place that involves an exchange of ions (charged particles) and electrons. By using different metal pairs a voltage can be produced which in turn allows for an electrical current. A fruit battery is an example of electrochemistry, which forms the basis of all batteries.

Note: many pupils will incorrectly think that the electricity is somehow contained within the fruit/vegetable.

Electricity 101

Although not strictly required, an understanding of some of the key terms and concepts can be useful within the context of this investigation.

Conductors, such as metals, conduct electricity because they contain particles called **electrons** which are free to move around. An electric **current** is simply the flow of these free electrons. A useful analogy can therefore be drawn between the current in a river and a wire, with electrons taking the place of the water. The larger the current in a wire, the faster the electrons are moving. Insulators do not have free electrons and so do not conduct electricity.

When electrons move through a conductor they carry **energy**. For example, in a simple circuit the electrons pick up energy stored in a battery and transport it to a bulb. **Voltage** provides an indication of how much energy each electron is carrying. The higher the voltage the higher the energy each electron possesses.

Care of Kits

Please ensure that kits are wiped down after use. The metal electrodes should also be wiped/rinsed to avoid oxidation and the formation of a rust/patina layer. A slight colour change is normal due to the chemical reaction that takes place.