Working scientifically with fruit and vegetable batteries

Andy Markwick and **Amy White** outline how the well-known fruit-and-vegetable battery experiment can be an effective platform to support learning through exploration

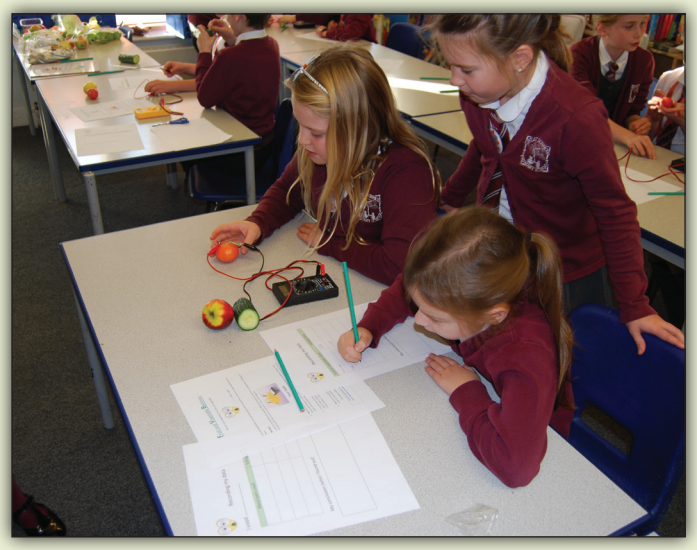


Figure 1 The children worked in groups to compare voltage readings from different fruits and vegetables

Previous articles in *Primary Science* have presented a range of ways to teach electricity in engaging and informative ways (e.g. Buckley and Harvey, 2014; Chapman, 2014; Norman, 2014; CLEAPSS, 2016) and Frank Harris provides an interesting historical account of the development and use of batteries in *School Science Review* (Harris, 2019). This article builds on these earlier articles by showing how the well-known fruit-and-vegetable battery experiment can provide an effective platform from which children can work scientifically. Examples of work from year 4 (ages 8–9) and year 6 (age 10–11) children demonstrate how outcomes are naturally differentiated. Each example shows children asking questions and working cooperatively to obtain data from experiments to solve problems and draw conclusions.

Before you use these examples in your classroom, it is envisaged that the children will have been introduced to cells, batteries, closed/open circuits and possibly electrical energy, ideally through practical activities, and that they are able to construct simple series circuits. Tables 1 and 2 show the range of scientific and mathematical skills developed in the activity and suggested sources of evidence.

Structuring learning

In addition to knowing how to construct a simple circuit, children will need to be introduced to a voltmeter and how it is used to measure electricity in volts (Box 1). This was achieved by connecting the voltmeter to a battery (e.g. 9 V). Children were asked to say what the voltmeter reading said and then read the battery's voltage rating (usually found on the side of a battery).

The next stage demonstrated how a simple fruit cell could be constructed by pushing two different metal electrodes into a fruit and connecting these to a voltmeter (Figure 1).

The activity was structured by asking children the questions below.

Which fruit or vegetable produces the greatest voltage?

Children used the same pair of electrodes and changed the fruit or vegetable. For each fruit or vegetable, voltage readings were recorded in a table (this was provided). Figure 2 shows representative tables and conclusions completed by year 4 and year 6 children respectively. It is evident that both year groups were able to confidently and accurately obtain and record data and draw conclusions.

Most year 4 children were able to suggest which fruit/veg would give the

Key words: Working scientifically Electricity

Table 1 The range of key skills developed in working scientifically (LKS2, italics UKS2)

Working scientifically statement	Evidence
Asking relevant questions and using scientific enquiry to answer them.	For example: 'Which fruit or vegetable gives the highest voltage?'; 'Which pair of metals gives the highest voltage?'; 'What is the combined voltage of two fruits? Is this what I measured?'
Setting up simple practical enquiries, comparative and fair tests. *Planning different types of scientific enquiries to answer questions, including recognising and controlling variables where necessary.*	Children plan and set up their own apparatus to answer the questions raised. They consider how to introduce fair testing.
Making systematic and careful observations and, where appropriate, taking accurate measurements using standard units. *Taking measurements, using a range of scientific equipment, with increasing accuracy and precision.*	Children use multimeters to measure and record voltage readings (in volts). Meters are set to measure voltage to 2 decimal places.
Gathering and recording data to help in answering questions and recording findings using simple scientific language and tables.	Data obtained by children are recorded in tables [tables were prepared for children to save time]. Children are asked to use their data to answer the questions they raise. Children are encouraged to use scientific language.
Reporting on findings from enquiries, including oral and written explanations.	Children are continually challenged by being asked searching questions, such as 'What did you find out?'; 'Why do you think your prediction was incorrect?'; 'What is happening to make the electricity?'
Using results to draw simple conclusions, make predictions for new values. Using test results to make predictions to set up further comparative and fair tests.	All groups were asked to discuss their results and write a simple conclusion: What did they find out?; Were their predictions correct? Children set up experiments to solve further problems.

Table 2 The range of key skills developed in working mathematically (years 4 and 5)

Working mathematically statement	Evidence
Year 4	
Add and subtract numbers with up to 4 digits.	Children measure and manipulate numbers with 2 decimal places (dp).
Round decimals with 1 decimal place.	Numbers have been rounded up from 2 dp to 1 dp.
Compare numbers with the same number of decimal places.	Children compare the values to present them in order of largest to smallest.
Year 5	
Solve problems involving numbers up to 3 decimal places.	Children used their results to determine combination voltages and suggest reasons why measured values were less than predicted.

Box 1 Voltage – an explanation

Electricity can be thought of as a flow of electrons. The rate at which this flow occurs is the current and is measured in amperes using an ammeter.

Voltage can be thought of as a measure of how much energy is transferred from one electrode to another for a given amount of charge (a number of electrons called a coulomb). Voltage is measured in volts (also joules/coulomb) using a voltmeter. It measures the difference in energy between two points. Current will only flow if there is a difference in energy between the electrodes.

In a fruit/veg battery the metal electrodes react with the acids (citric acid and ascorbic acid or vitamin C) to produce electrons that have increased energy. The amount of energy the electrons have is determined by the reactivity of the metals. For a current to flow a potential difference (difference in energy) is required. If there is no potential difference, for example the same metals are used, electrons will not flow (no current) and the voltage will be zero.

highest reading and state this. Some children were able to offer verbal explanations, such as '*lemon has more acid*' and '*there's more juice in it*'. The evidence also suggests that children understood fair testing: '*To keep it a fair test you could put the metals in the same distance down* [depth?]' and '*I made sure I used zinc and iron each time*'.

Year 6 children were able to predict and draw similar conclusions to year 4 children. However, some also offered written explanations, such as '*The highest voltage came from fruits with the higher citric acid levels. The citric acid reacts with the metals*'. Fair testing was also considered and in general

explained in more detail: '*To keep it a fair test you could put them* [metals] *the same distance apart and the same distance* [depth] *into the fruit*'.

Time was provided for children to discuss their results and to consider their supporting evidence in drawing conclusions. This process helped children to develop their argumentation skills and therefore develop their science communication and knowledge building (Russell and McGuigan, 2016).

What happens to the voltage when a battery is made from more than one fruit or vegetable?

Groups chose a pair of fruit/veg and kept the metal pair the same. This activity challenged both year groups. Once a group had solved the problem of creating a battery from fruit and vegetable pairs, they were asked to demonstrate this to the class (Figure 3).

Figure 4 shows representative tables and conclusions from year 4 and 6 children respectively. Both year groups were able to construct batteries and record voltages to 2 decimal places. Children were able to predict battery voltages by calculating (adding) values from each component cell and compare this to their actual result with good accuracy.

Year 4 children were able to interpret their results, stating whether their actual values were more or less than their predicted values. Some were able to offer explanations for the differences, such as '*I set them up differently*' and '*The electrodes might have been put in at different depths or distances apart*'.

Year 6 produced very similar results and gave more detailed explanations, possibly because their literacy skills were more developed.

Which pair of metals produces the greatest voltage?

Groups chose a fruit or vegetable and changed the metal pairs used (Figure 5). Both year 4 and 6 groups were able to successfully undertake the activity and record their data in tables and to draw conclusions (Figure 6). Both year groups identified copper and zinc as the metal pair that produced the highest voltage, and both noticed that using the same

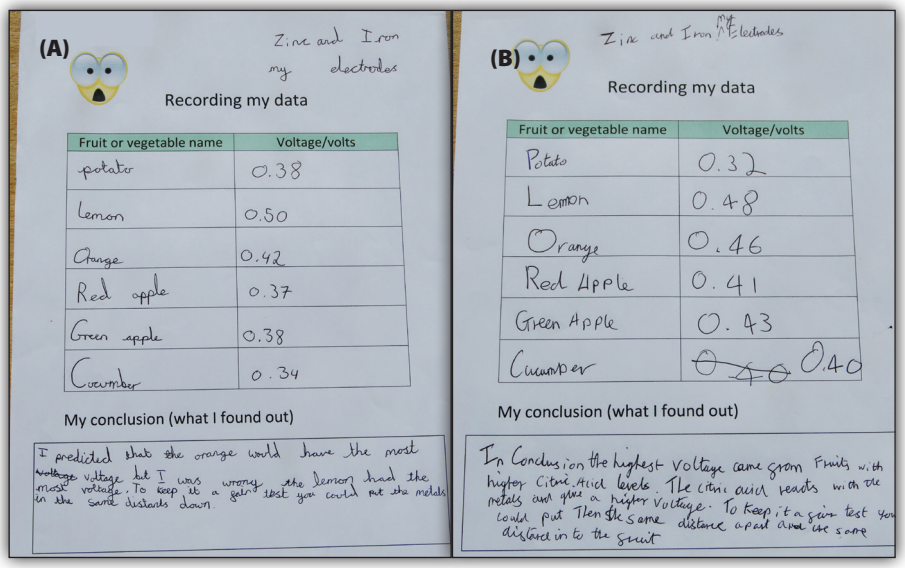


Figure 2 Results tables and conclusions from children in year 4 (A) and year 6 (B) comparing the voltage from different fruit/veg batteries

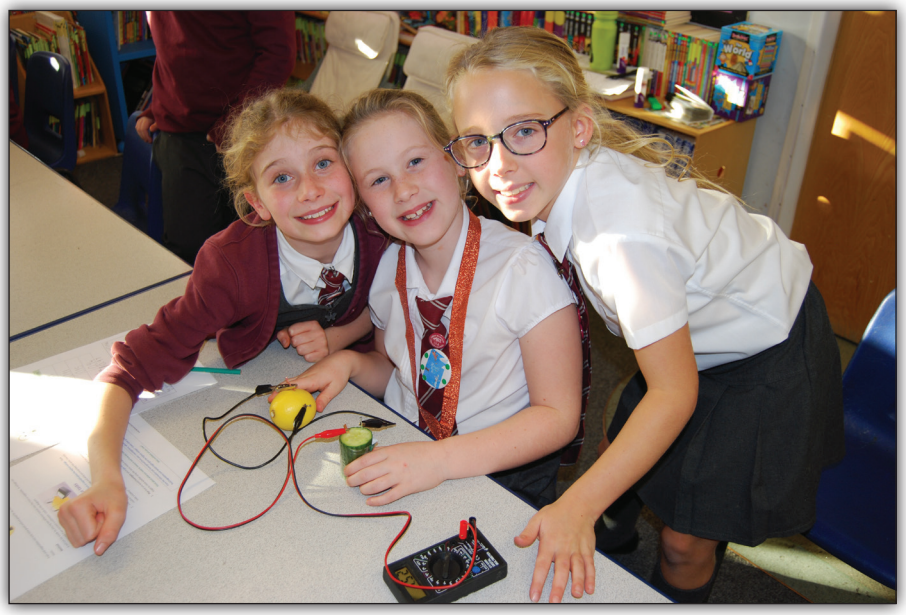
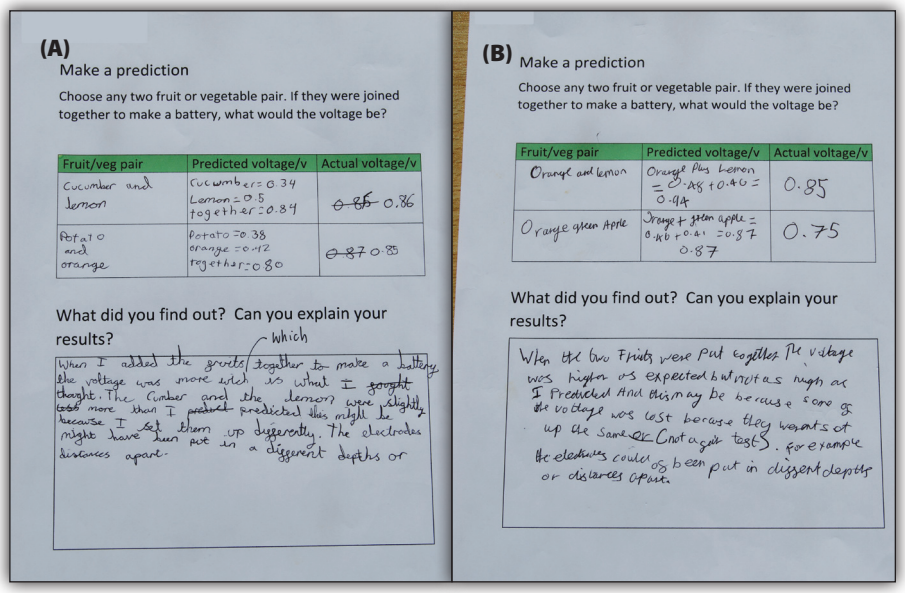


Figure 3 This group worked out how to create a battery using a pair of fruit/veg



Figures 4 Results tables and conclusions from year 4 (A) and year 6 (B) comparing different fruit/veg pairs

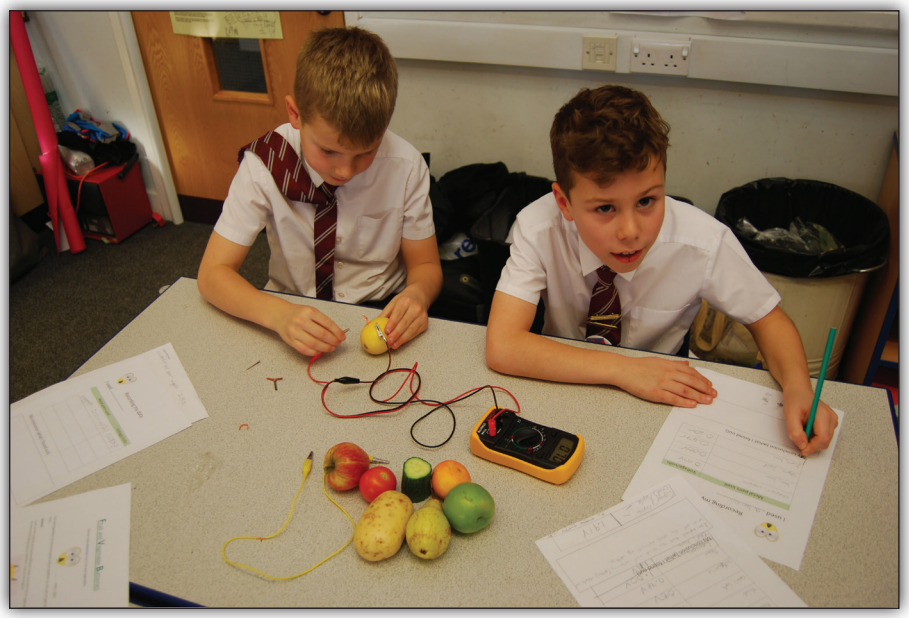


Figure 5 Groups experimented with different pairs of electrodes

metals gave no voltage. Several year 4 children concluded that if a voltage was required, the same metals could not be used (Figure 6A), whereas some year 6 children went further and considered the reactions occurring at each metal surface (Figure 6B). When asked to describe what they had found out one pupil stated: '*The different metals react differently each making electrons* [electricity] *with different amounts of energy*' and '*The same* [pair of] *metals make the same energy. This means no potential difference* [voltage]'. It is clear from the conclusion in Figure 6B and in discussion with pupils that children are beginning to link chemical reactions to the generation of electricity and to understand that the flow of current is dictated by the potential difference between the electrodes.

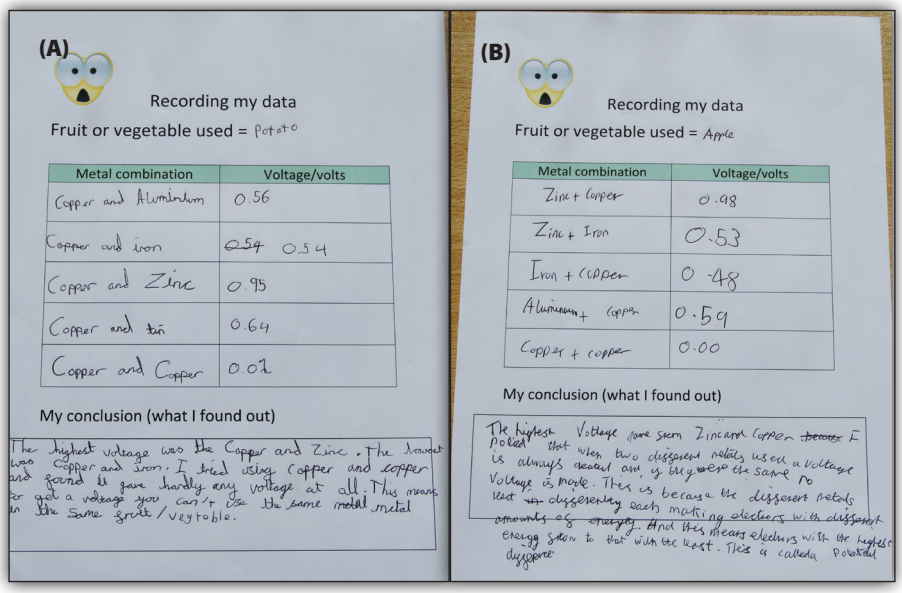


Figure 6 Results tables and conclusions from year 4 (A) and year 6 (B) using different pairs of electrodes

In conclusion

This activity provided children with many opportunities to develop their scientific and mathematical skills and for teachers to assess mastery in these areas. In addition, ideas about closed and open series circuits were reinforced and children were introduced to how electrical energy can be produced by chemical reactions. To extend the activity children can be placed into a series circuit with a fruit/veg cell (or battery) and a voltmeter. If they all hold hands (the circuit is closed) the voltmeter will record a voltage. If any child stops holding hands (open circuit) the voltmeter reads zero. This demonstration also shows how electricity can flow through our bodies, which can lead to a discussion of the dangers of electricity in the home.

Andy Markwick is a lecturer in science education at UCL Institute of Education, a PSQM hub leader and an Independent STEM consultant.
Email: andy.markwick@ucl.ac.uk;
Web: www.stemconsultancy.co.uk
Amy White is a primary school teacher and science coordinator at Great Dunmow Primary School in Essex.
Email: a.white@greatdunmow-pri.essex.sch.uk

References

Buckley, A. and Harvey, K. (2014) 'Squishy circuits': a novel way of teaching electricity – with playdough! *Primary Science*, **135**, 12–14.

CLEAPSS (2016) Using conductive (copper) tape in circuit work. *Primary Science*, **141**, 25.

Chapman, S. (2014) Teaching the 'big Ideas' of electricity at primary level. *Primary Science*, **135**, 5–8.

Harris, F. (2019) Batteries: from excavations to electric vehicles. *School Science Review*, **100**(372), 9–12.

Norman, K. (2014) The 'Reds and Blacks': Developing 10–11-year-olds' understanding of electricity. *Primary Science*, **135**, 36–37.

Russell. T and McGuigan, L. (2016) *Exploring science with young children: a developmental perspective*. London: Sage.

Useful weblinks

Build a lemon-battery (scienceandmath.com): www.youtube.com/watch?v=Pq3yjsVQbXA

Fruit-power battery (Sick! Science): www.youtube.com/watch?v=XtHt00AN0pU