

ELECTRICKERY

Steven Chapman shares some salient points about teaching this tricky but fascinating subject

TEACHING THE

'BIG IDEAS'

OF ELECTRICITY AT PRIMARY LEVEL

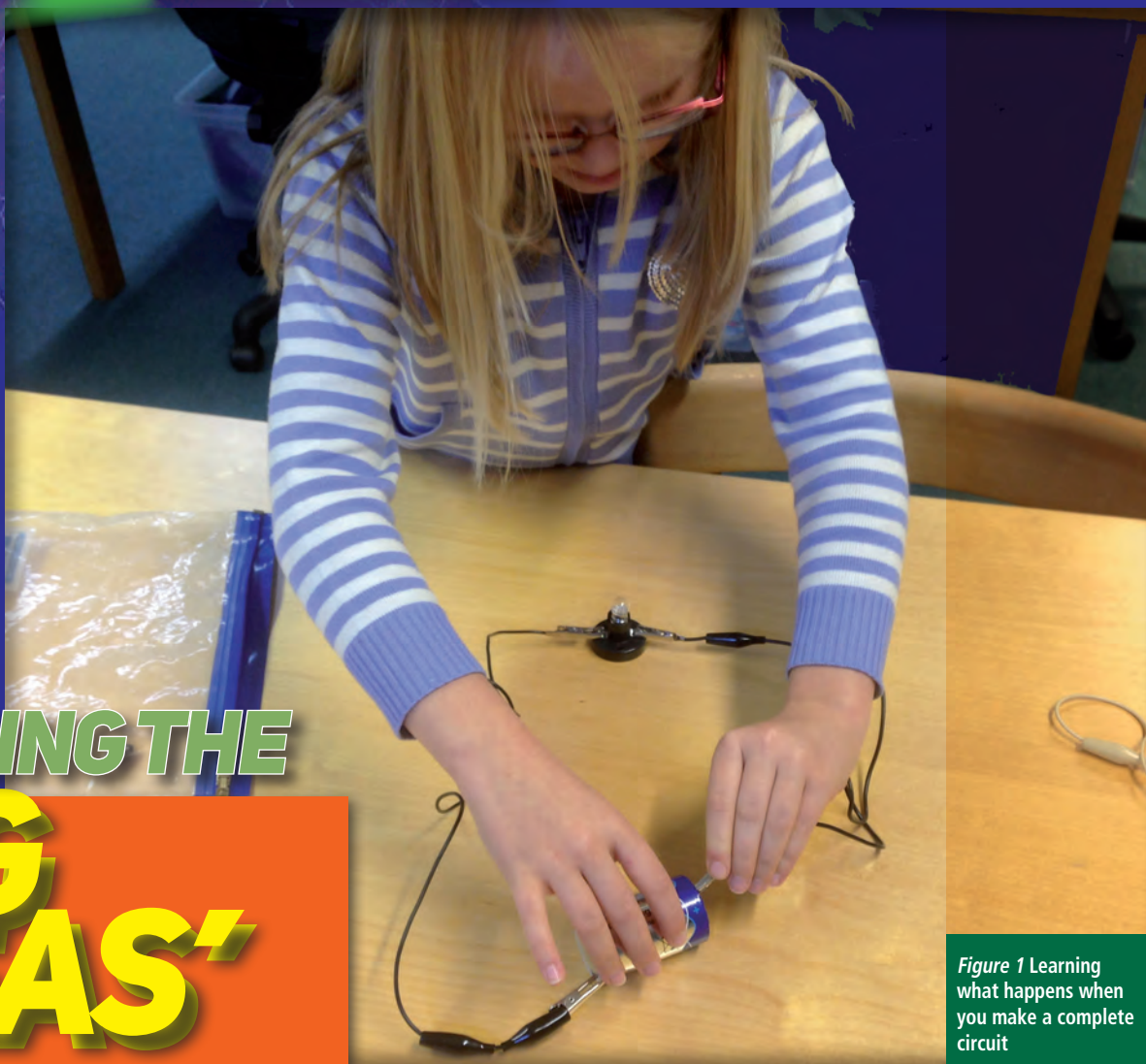


Figure 1 Learning what happens when you make a complete circuit

Electricity can be a fun topic at primary school that includes many practical experiments and links to real-life contexts. However, teachers can feel daunted by the subject as they think they do not know enough about the science behind it to answer off-topic questions. The reason for the difficulty is that much of the science takes place inside a wire: electricity is seen only by its effects.

Much work in school science has traditionally taken a *phenomenological* approach; in other words, we look at *what*

happens and try to map that rather than *why* or *how* something happens. For example, adding a second battery makes the bulb brighter, or we only get a bulb to light when we have a complete circuit of conducting material (Figure 1). Even at secondary school, when new concepts such as charge, current and potential difference (voltage) are introduced, we only really begin to dip our toes inside the wire and start to build up a sketchy picture of what is actually going on at this minute scale.

One clear message does begin to come through, however: because we cannot see inside the wire, we need models and ideas to help us understand more clearly. These models link the microscopic world of the charges to the macroscopic world of bulbs, cells and wires.

So what are the big ideas about electricity and how can we approach teaching them?

Teaching physics to young children

Obviously, the best way of teaching any subject is by

Key words:
Physical processes
Types of activity
CPD



Figure 2 There is a big gap between the range of electronic gadgets children use as part of their everyday life and what we provide in school!

Box 1 Big ideas in electricity

- **Electric current.** As charges move around the circuit they form an electric current. The charge passing any point in one second is the electric current (measured in amperes or A, using an ammeter). A big current can be made using either a lot of charges or fast-moving charges or both.
- **Potential difference (voltage).** As the charges move around the circuit they carry energy. The voltage is a measure of how much energy is being moved around the circuit, for example from a battery or cell to a lamp. It is the energy that each unit of charge carries and it is measured in volts or V.
- **Resistance.** Although everything in a circuit is a conductor, some conductors (such as wires) are better than others (such as lamps). We use the idea of resistance to explain how easy or difficult it is to pass current around a circuit. It is defined as the number of volts needed to get one ampere of current to flow in a material and is measured in ohms (Ω).

starting with children's existing knowledge and building on those ideas. Electricity is not an easy topic and even at a simple level it contains abstract ideas and phenomena. There is also a disconnection (no pun intended) between what a child might see relating to electricity in their everyday life and the small coloured leads and paper clips we use to explain electricity in schools (Figure 2). There is a wealth of information in the literature about children's ideas about electricity and many long-out-of-print but valuable resources are available on the National Stem Centre and Nuffield Foundation websites (see end).

A good place to start is to look

at the key concepts involved in electricity and how they relate to the big science ideas (Box 1).

Key starting points and concepts

Complete circuits

- Electricity flows when we have complete loops of conductors, or circuits. Only when these complete loops exist, does anything happen with electricity.
- Circuit diagrams look very different from what is in front of the children in the classroom (Worcester

Circuit Boards can help with this – Figure 3).

- You can have more than one loop in a circuit and this can be really useful for doing certain jobs (parallel circuits).

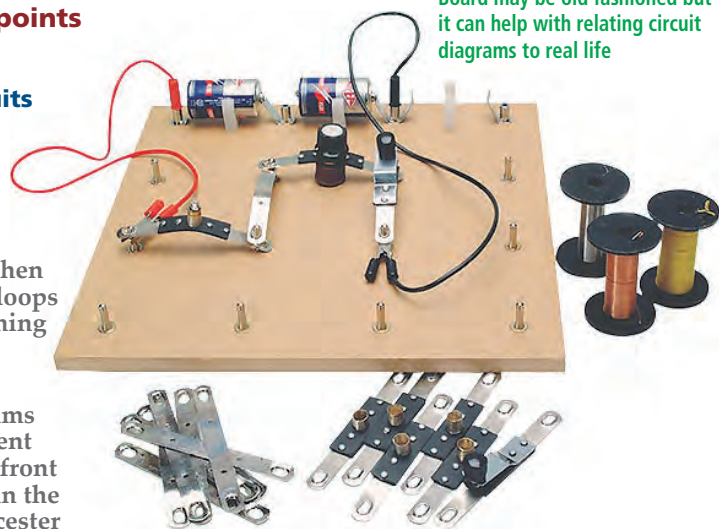
What is happening inside the wire?

- Charges are already in the wire and they can move (Box 2). They are not added to the wire by anything else in the circuit (such as a battery).
- The charges carry energy around the circuit.
- This movement of energy is what makes the things we see happen. For example, it makes the light come on or it makes the motor turn.
- We can make energy move faster or slower depending upon what we add or take away from a circuit.
- Even though the charges are tiny particles, they are all electrically negative and are therefore repelling each other. This means that instead of acting as individual particles they all repel each other and act collectively. This is important as it makes things happen very quickly in a circuit.

Using models and analogies (Box 3)

- We use models and analogies to explain what is happening inside the wire. We cannot see inside the wire and if we cut the wire open we would stop it working as it would break the loop.
- There are scientific models that use mathematical ideas and physical constructs to predict

Figure 3 A Worcester Circuit Board may be old fashioned but it can help with relating circuit diagrams to real life



Box 2 Teaching about electric charge

One of the problems that teachers face is what to tell pupils about what electricity is made from. Even at secondary school, electric current is introduced in year 7 (ages 11–12) but the electron is not introduced until year 10 (ages 14–15), when pupils study atomic structure. Do you want to introduce a subatomic particle before the idea of atoms has even been mentioned?

It is possible to talk about charges without mentioning electrons. In fact, much of the science of electricity was worked out before the electron was discovered in 1897. This is why, for example, electricians' current travels from positive to negative, when in fact electrons actually travel from negative to positive.

So one approach might be to talk about small particles that carry something called 'charge'; these charges cause all of the electrical effects we see happen. Then to say something like:

There are two different kinds of electricity called positive and negative charges. Just like the poles of a magnet, opposite charges attract and like ones repel. All of the phenomena we see are caused by these charges being pushed and moving about within wires.

what goes on inside and outside the wire. Most of these are ideas that are taught at university level.

- To help explain things to young people we use analogies such as carrying sweets in cups. These help them understand and predict what is going on in the wire in simple terms. They should not, however, be at odds with the scientific models.

- Each analogy needs to explain clearly how the real circuit relates to the model. For example, what is the battery in the analogy? What is the bulb?

- The most crucial aspect of using an analogy or model is knowing its limitations. What does it explain well? Where does it fall down?

Children's misconceptions about electricity

There is a wealth of literature about children's alternative conceptions in electricity (for example, Driver *et al.*, 1994; Osborne *et al.*, 1991), but very little about primary school children's ideas (see Glauert, 2009, for a rare example). A number of major misconceptions keep coming up and often persist, even after good, and repeated, teaching over an extended number of topics and years. Many teachers also share these misconceptions, which shows how hard they are to shift. Examples are:

- Current is used up by the components in a circuit. Current

flows from the battery to the bulb, where the current is used up by the bulb, and then whatever little current is left goes back to the battery.

- When a switch is closed you have to wait for the current to travel from the battery to the bulb before it can light. This implies that charges are given energy by the battery one at a time and we have to wait until the first of these energised charges reaches the bulb, however far away it is.

- Charge is carried in batteries and then added to the circuit when it is connected, reflecting the belief that there are no charges in the wire and that they are added to the wire from the battery; when they have run out the battery is flat.

Box 3 Types of models and analogies

the wire. They fall into two broad types:

- **The delivery model.** In this analogy, something is being delivered from one place to another to simulate energy being shifted from a battery or cell towards a component (such as a bulb or a motor). This can be a bakery delivering bread to shops, a mine delivering coal to power stations, or children delivering sweets around a loop. In each case, you need to think carefully about how each part of the analogy matches part of the real circuit. The model is very good

Teachers use many different models and analogies to explain what is going on inside

for getting all of the pupils engaged in role-play, and can be used to explain ideas about current flowing all around a circuit. It does fall down, however, when trying to explain how energy is shared between two bulbs in a circuit or why circuits appear to work instantly.

- **The loop model.** In this analogy, the charges form a chain or loop, so once one part of the loop starts moving every part of the loop starts moving. This is really useful for explaining how energy is shared between bulbs or, by using multiple loops, how parallel circuits work. Rope loops, bicycle chains or any connected loop may be used to explain how charges move. This is a very powerful and useful model.

- Current = voltage = energy = electricity!

- Batteries or cells give out only one current when connected, whatever is in the circuit.

These are some of the most common alternative ideas seen in classrooms. Anticipating what might come up is a crucial way of planning responses to the questions that may occur.

Teaching hints

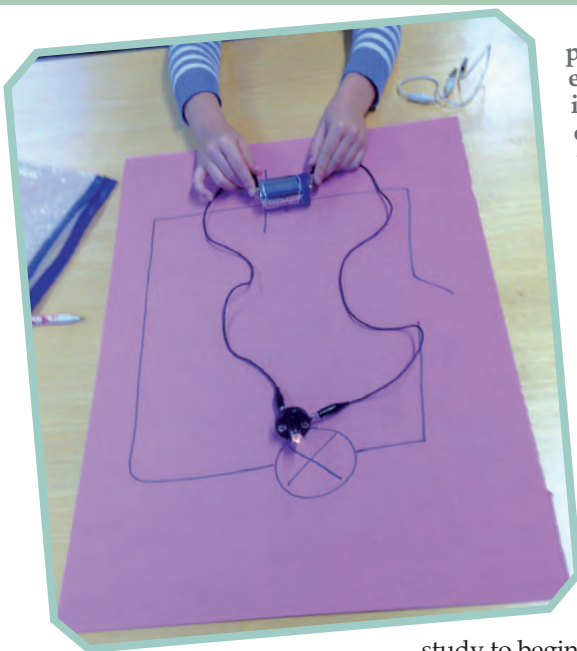
- **Start with phenomena and move on.** Before moving inside the wire and trying to explain *why* things happen, think carefully about how you can ensure the children have a secure understanding of *what* happens in circuits.

- **Use experimental evidence** to facilitate and close down discussion. Ask for the children's predictions about what will happen when the switch is closed. Then use the experimental results to try to get the children to evaluate their ideas.

- **Use models carefully** and make sure you understand both their value and their pitfalls. The delivery model or sweet model is a good way of thinking about why current is not used up in a circuit, but it is not very helpful for more than one bulb. Understanding where a model breaks down is a great sign of deep understanding of an idea.

- **Anticipate their misconceptions** and think of ways to move around them. If you think the children will predict current being used up, set up an ammeter before and after the bulb.

Figure 4 Drawing a diagram on sugar paper and then putting the components on top can help children to see what the real circuit looks like



- **Use sugar-paper templates** to help guide the children on where to lay components and wires (Figure 4). This will make it easier for you as a teacher to unpick any wrong connections.

- **Think about the purpose.** There is some research evidence that young children's ability to connect circuits confidently is not linked to their ability to understand what is going on. So think carefully about the

purpose of the experimental work: is it to understand circuits or to test their ability to build successful ones?

Finally

Electricity is a fun topic and it is great fun to build circuits. It is also a very complex and abstract subject. It has taken scientists hundreds of years of advanced mathematical

study to begin to get to grips with it. After many years of teaching electricity and much thought and study I have a slightly lower level of misunderstanding than when I first started teaching!

References and further reading

Driver, R., Squires, A., Rushworth, P. and Wood-Robinson, V. (1994) *Making sense of secondary science: research into children's ideas.* London: Psychology Press.

Glauert, E. B. (2009) How young people understand electric circuits: prediction explanation and exploration. *International Journal of Science Education*, 31(8), 1025–1047.

Osborne, J., Black, P., Smith, M. and Meadows, J. (1991) *SPACE Project Research Report: Electricity.* Liverpool: Liverpool University Press.

The Institute of Physics has been developing some resources to help primary school teachers with teaching physics. These will be available gradually as they are developed at <http://supportingphysicsteaching.net>

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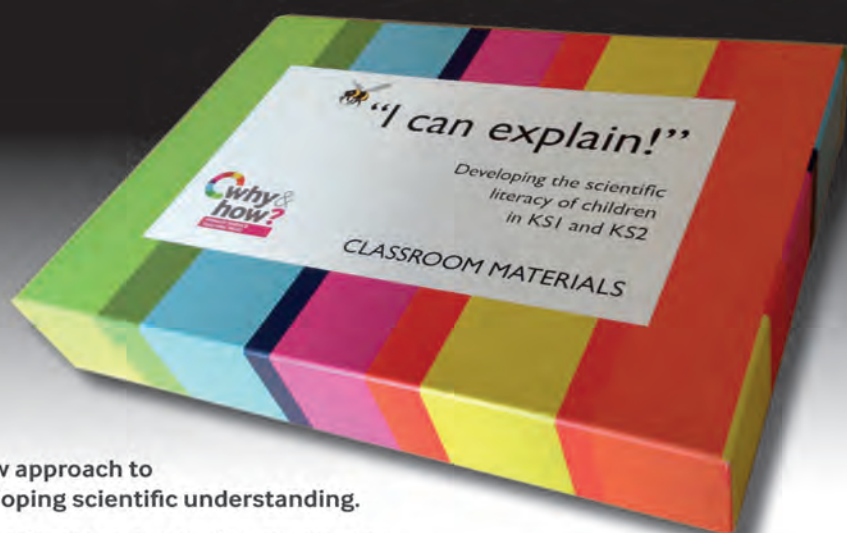
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