Electricity and Magnetism: Teaching and Learning Issues 01

Contents

This is the ‘Teaching and Learning Issues’ that explains the particular challenges. To develop your expertise in the episode, work with the ‘Physics Narrative’ and the ‘Teaching Approaches’. Navigate to any part of the topic using the Topic Menu, or use the tabs below to stay within this episode. .

Pupil starting points

The key challenge of this episode is for the pupils to come to understand how electric circuits work in terms of objects and ideas (such as charges and energy) which they can neither see nor directly experience. The pupils need to be able to explain and visualise the working of electric circuits in terms of charges, current, energy and resistance.

As youngsters enter secondary school and study electricity, they are already using a wide range of electrical appliances confidently, and very often extremely competently. They take for granted that these things must be switched on, cost money to run, can work from batteries or from being plugged in, can be dangerous and so on. Through these experiences of using electrical equipment, and from their work at primary school, your pupils will have developed some basic ideas about how electrical appliances work.

We asked a group of 11 year-olds about their understandings of how electrical appliances and electric circuits work. What they had to say makes for interesting listening!

Pupils views on electricity

Clip 1 | Clip 2 | Clip 3 | Clip 4 | Clip 5 | Clip 6

Helpful and unhelpful ideas about electric circuits

From these video clips, and from research that has been carried out more widely, it seems that youngsters of this age typically have the following kinds of ideas about electric circuits.

Right lines	**Wrong track**
Complete circuit	
No gaps	
Energy from battery	Battery stores electricity
Electric charge flows	Electricity from both ends of the battery
Current in components	
Add a battery for brighter bulb	Electricity used up
Extra battery gives more energy	Battery runs out of charges
The battery runs out of energy	Battery runs out of electric currents
	Shorter connecting wire needs less electricity

Some of these ideas are consistent with a sound model of electricity and we refer to these as being along the “right lines”. Others are not consistent with this view and see the pupils going ”down the wrong track”.

One obvious point is that pupils do arrive at secondary school with understandings of electric circuits, which are along the right lines and can therefore be built upon in subsequent teaching. Next we consider, in a little more detail, some of the key right lines/wrong track pairs for electric circuits

Try diagnostic questions

Our experience suggests that there is not a big variation in the views that youngsters of this age bring to their science lessons. Nevertheless, it is a good idea to probe the understandings of your pupils at the start of any lesson sequence or module, and so we have provided three diagnostic ("think again!") questions, which you might use.

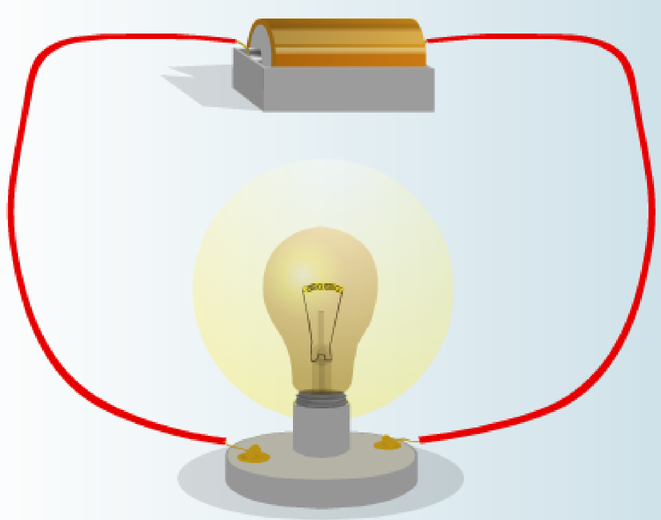
Try diagnostic questions

Here are some responses of 11-year-old pupils to the simple circuit "think again" questions.

The pupils had just started secondary school and had received no teaching on electricity in the secondary school. These are the verbatim responses of the pupils complete with one or two spelling mistakes!

The pupils' original completed sheets are also available as pdfs.

Some thoughts to dwell on | PUPIL 1 | PUPIL 2 | PUPIL 3 | PUPIL 4 | PUPIL 5 | PUPIL 6 | PUPIL 7 | PUPIL 8 | PUPIL 9



This is a very simple electric circuit

1. Explain in as much detail as you can (thinking about battery and bulb) **why** you think the bulb lights up.

2a. How could you change this circuit to make the bulb brighter?

2b. **Explain why** this would work

3. If the circuit is left, **why** will the battery go flat eventually?

Pupil 1:

1. The bulb lights up because the electricity goes through wire to the bulb from the battery which lights up the bulb

2a. You would put in another battery

2b. It would be brighter because there is more energy in two batteries than one

3. Because batterys only have a certain amount of energy in them so when left to long it will go flat.

Challenges faced in getting started

- Challenge 1: Where do the charges come from?
- Challenge 2: The charges move all together
- Challenge 3: Distinguishing between current and energy
- Challenge 4: Putting it all together, the basic electric circuit model

These challenges reflect research carried out into alternative conceptions.

Challenge 1: Where do the charges come from?

Wrong track: “The charges all come out of the battery.”

The incorrect idea here is that the charges all originate in the battery and flow out from the battery to form the electric current.

Right lines: “The charges originate in the circuit”.

The charges originate in the circuit itself and are set in motion by the battery when the circuit is completed. They are simply parts of the atoms that make up the battery, wires and bulb. You might say that the charges “live in the wires”.

Careful with your language!

You need to be careful with your choice of words in introducing and talking about these basic electric circuit ideas. It is very easy to suggest incorrect ideas and have your pupils moving down "the wrong track"!

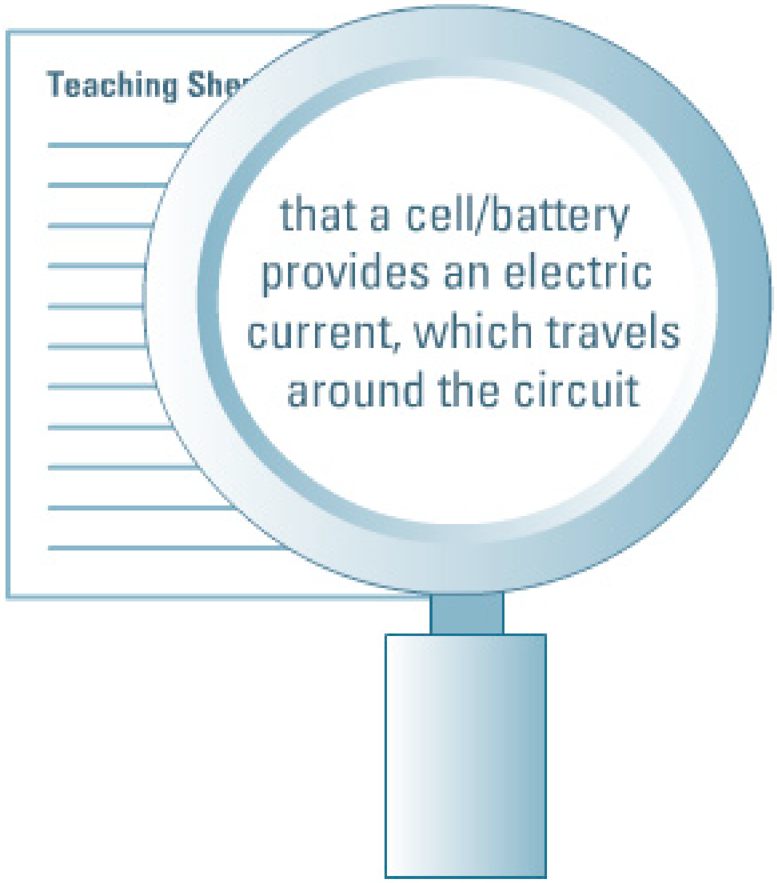
For example, in a published teaching scheme, it is stated that pupils should learn:

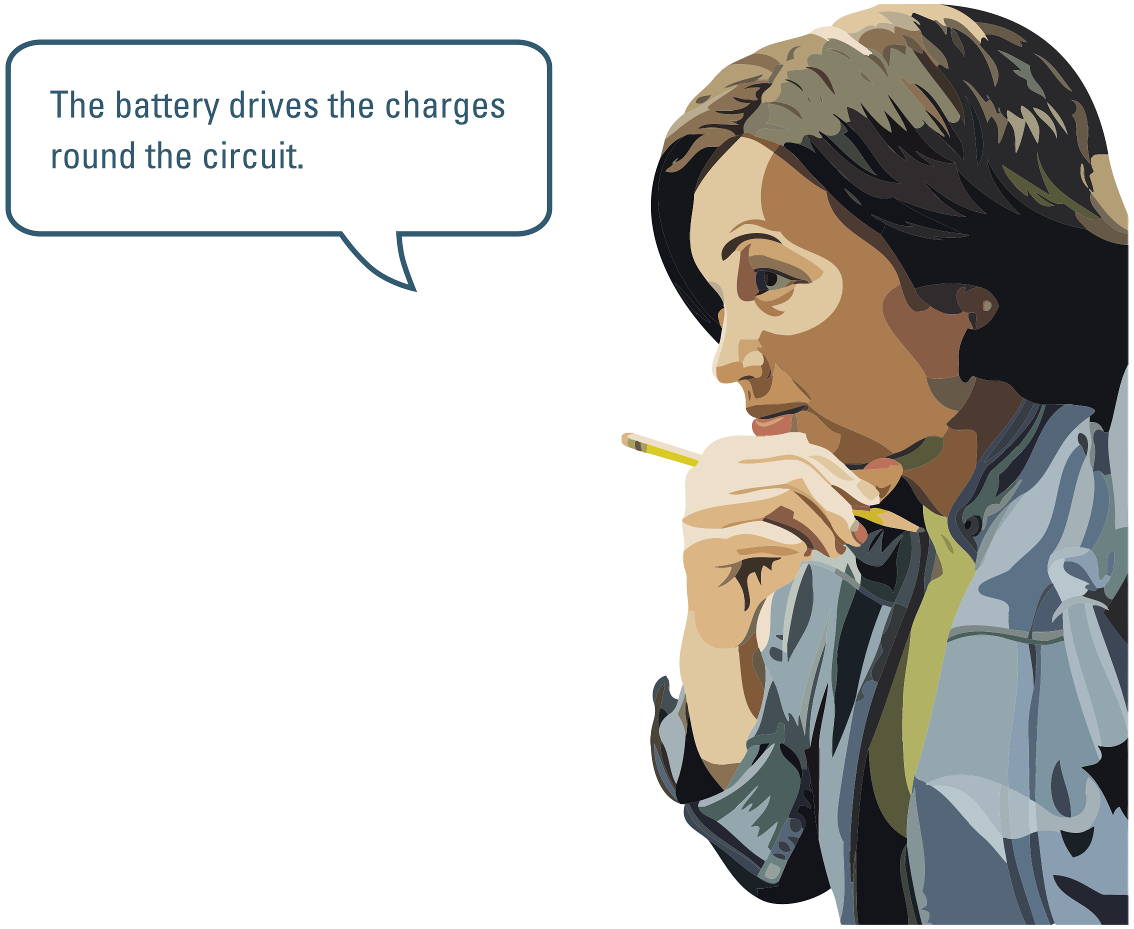
"that a cell/battery provides an electric current, which travels round the circuit"

We don't necessarily believe that the writers of this teaching scheme have got it wrong! We do, however, recognise that what is written is ambiguous at best.

To some it might suggest that the electric current originates in the battery. You will come across similar statements elsewhere.

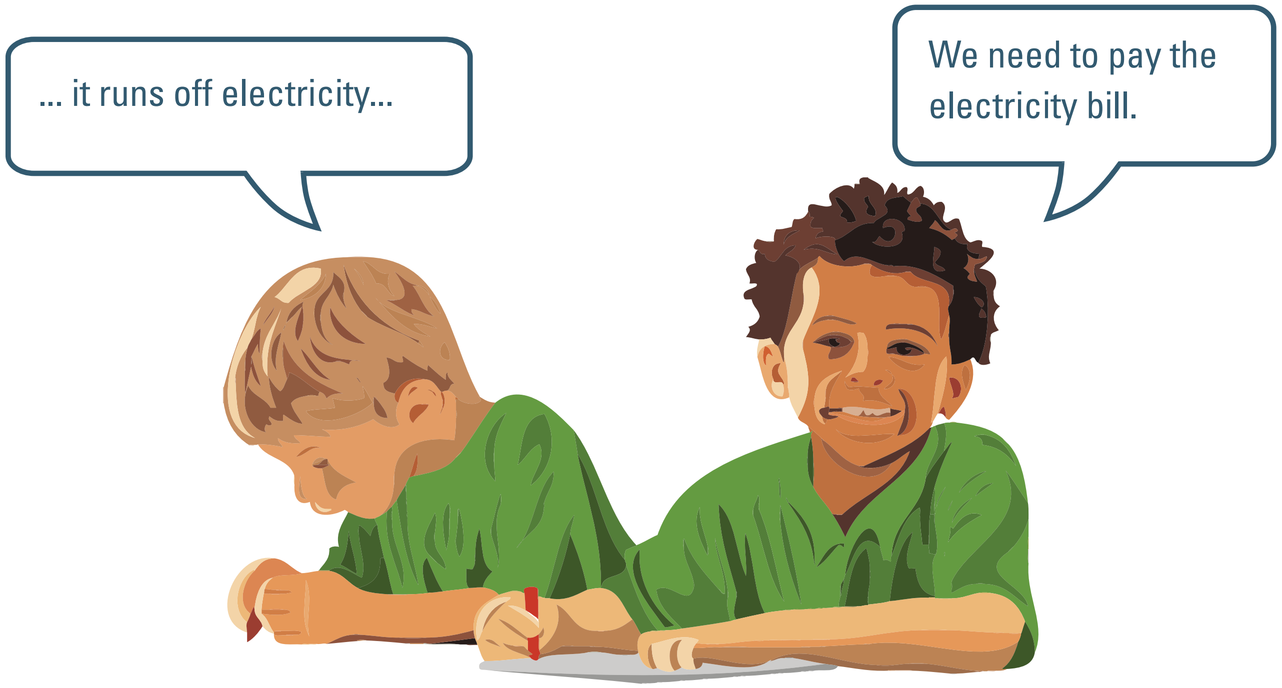
Try to avoid them in your own teaching! It would be better to say that:





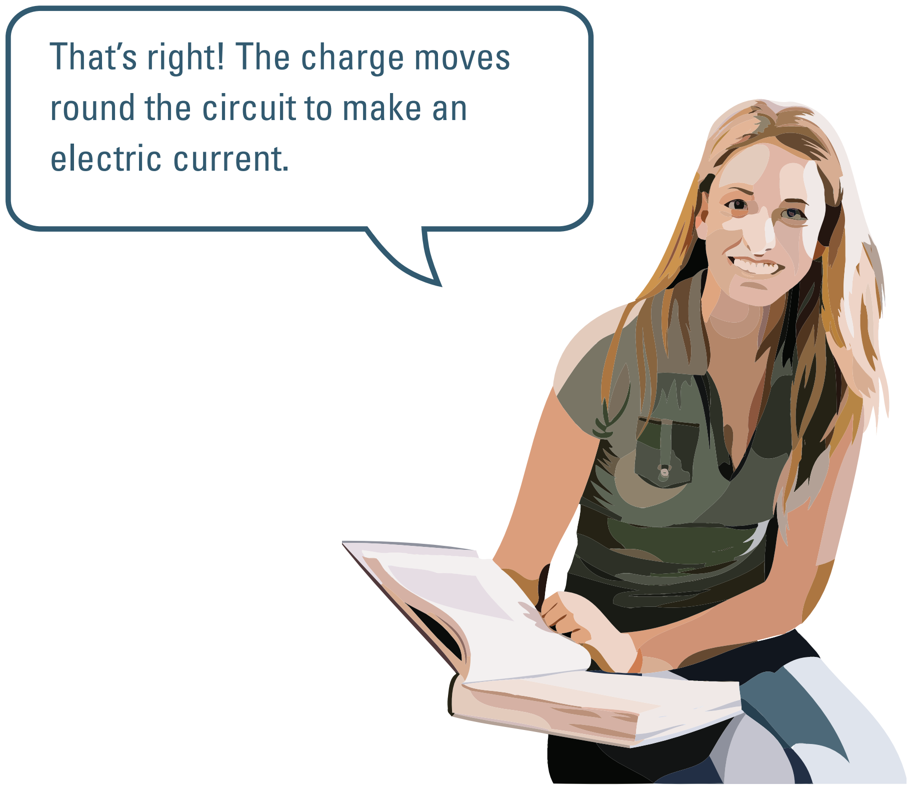
"Electricity": Being specific

In everyday speech the word "electricity" is very commonly used. Thus you might overhear statements such as:



This sort of expression inevitably carries over into school and so pupils might say:

Here you should encourage the pupils to be more precise in their use of terms: "What do you mean when you say that electricity flows? What is it that actually moves round the circuit?"



There aren't many situations where simply banning the use of a particular word is likely to help pupils come to understand and be able to use new physics ideas…but this might be one of those situations! A teaching colleague reckons that the only time he allows his pupils to use the word "electricity" is in writing the title in their books at the start of the new topic!

Challenge 2: The charges move all together

This is the same incorrect idea as Challenge 1, that the charges all originate in the battery and flow out from the battery to form the electric current.

Wrong track: When the switch is closed, the charges leave the battery and move around the circuit.

Right lines: When the switch is closed, the charges all around the circuit are set into motion together. When the circuit is completed, the charges start moving in all parts simultaneously. Those charges in the connecting wires, just before the bulb, move through the filament wire. Energy is transferred and the bulb comes on with no apparent delay. It is not a case of waiting for those charges that have just left the battery to arrive at the bulb before the bulb lights. There is a continuous and steady flow of charges in all parts of the complete circuit.

Don’t always start at the battery

When talking to classes about how electric circuits work, it is natural to start with the battery, which provides the energy for the circuit and sets the charges in motion. However, it is important to reinforce the idea to pupils that once a circuit is completed, the charges start moving in all parts simultaneously.

So, rather than pointing with one finger to trace the path of the current as it leaves one side of the battery, it is helpful to gesture with both hands together, showing the current simultaneously leaving one side of the battery and returning to the other side.

Challenge 3: Distinguishing between current and energy

The incorrect idea here is that when the charges pass through the bulb, they make the bulb light and so get used up.

Wrong track: The electric current gets used up in the bulb.

Right lines: Energy is shifted by the bulb. As the charges pass through the bulb, they encounter resistance in the filament, causing it to heat up and glow and the charges continue around the circuit back to the battery. Energy, and not the charges, is shifted by the bulb and dissipated.

Challenge 4: Putting it all together, the basic electric circuit model

Thinking about the learning

Pupils need to be able to picture what is going on as energy is shifted from battery's store to stores in the surroundings as the charges move around the circuit.

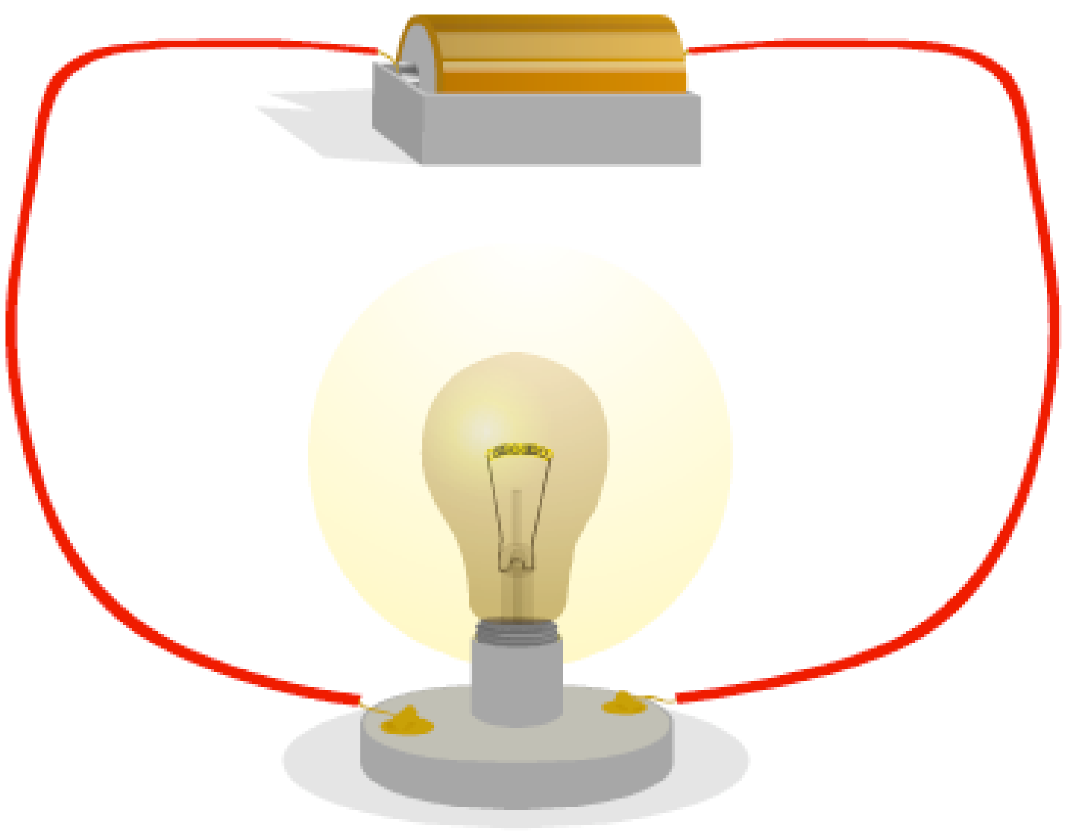
Thinking about the teaching

Because you are dealing with objects and ideas that cannot be seen, electric circuits present an interesting teaching challenge. We can think of two possible starting points for introducing the electric circuit model:

Direct approach: Develop an account based on charges flowing and energy being shifted.

Using a teaching analogy: First introduce a teaching analogy for the electric circuit as a starting point for developing the electric circuit model.

The advantage of using a teaching analogy is that it provides a familiar starting point for the pupils. The disadvantage is that analogies all have their limitations.



Two teaching analogies

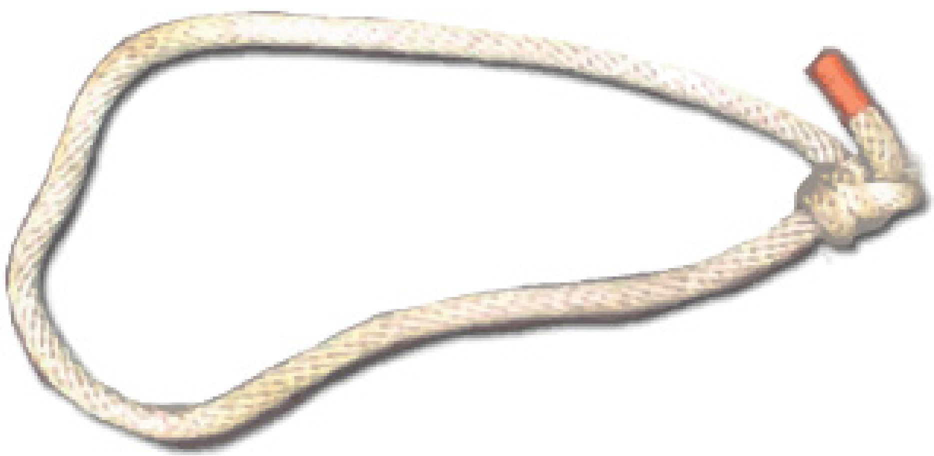
In this scheme we introduce and demonstrate the use of two teaching analogies:

The “rope loop”

The “supermarket picture”

Start with the “rope loop”

This first episode of the Physics Narrative focuses on where energy is shifted by componenets in the circuit: by the battery as it provides the push to maintain the motion of the charges, and by the bulb as the charges encounter the resistance of the bulb. We believe that the rope loop teaching analogy is particularly useful in representing this aspect of the model and we therefore suggest starting with this analogy.



Later you may introduce the “supermarket picture”

The supermarket picture teaching analogy is introduced in episode 3. It imay be useful in helping pupils to visualise where energy gets shifted in different circuits… but more of that later!

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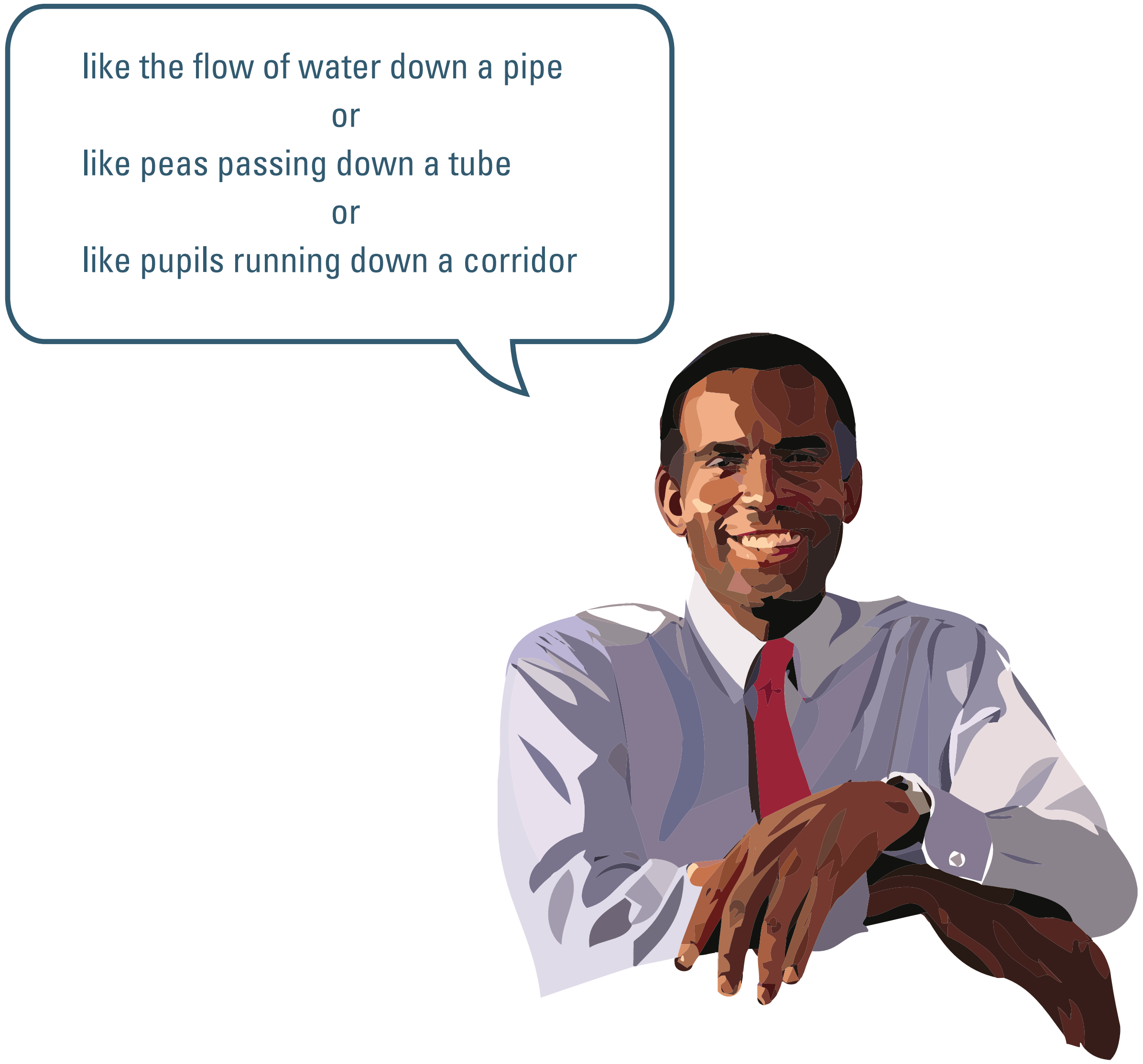
A systematic introduction to teaching analogies

Very often, analogies are drawn upon in teaching about electric circuits in an opportunist way, with the teacher perhaps briefly referring to the electric current as being, for example:



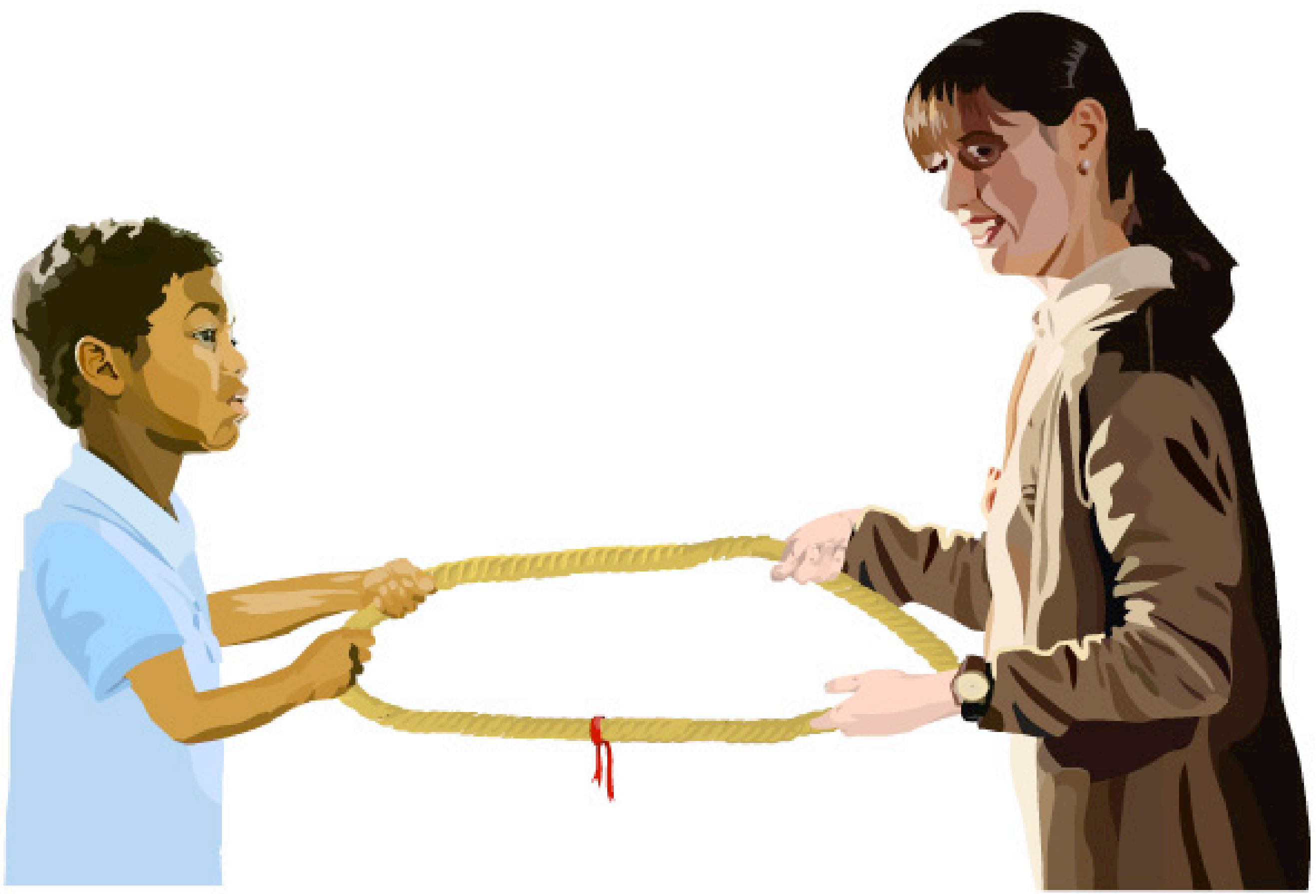
We believe that this can be confusing and recommend a more systematic approach in which the teaching analogy is carefully introduced:

Stages	**Things to say**
Step 1: Start with the electric circuit	This is what happens when the circuit is completed: the bulb lights. How can we explain why this happens?
Step 2: Introduce the teaching analogy	Let's think about something quite different: a loop of rope.
Step 3: Make links between teaching analogy and circuit	In what way is the rope loop similar to the electric circuit?
Step 4: Introduce the electric circuit model (through the analogy)	We don't have rope moving around the circuit, but we do have charges.
Step 5: Continue to refer to the teaching analogy as needed	So, why does the brightness of the bulb increase? You might want to go back to the rope loop in talking through your explanation.

A teaching analogy, used consistently, can help develop a mental model with which the pupil can reason on thier own. We think that this is a better outcome than just making the phenomena more plausible.

The rope loop teaching analogy

Imagine a loop of rope being held lightly by a class of pupils standing in a large circle. The teacher sets the rope in motion by moving it round from one hand to another. A piece of ribbon tied to the rope moves steadily around the circle. One of the pupils is instructed to increase the tightness (or resistance) of their grip. The motion of the rope around the whole circuit is slowed down.



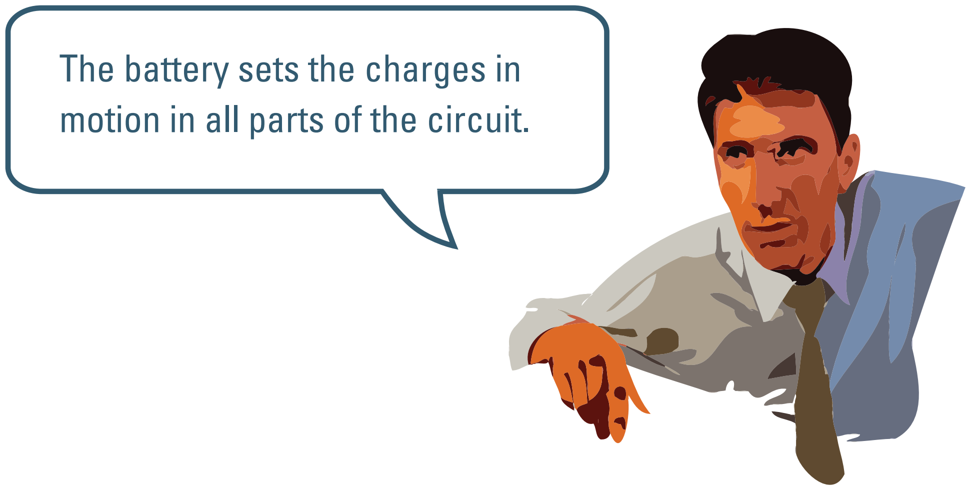
The basic links between the electric circuit model and the rope loop teaching analogy are as follows:

Electric circuit model	Teaching analogy: rope loop
The battery sets charges in motion around the whole circuit.	The teacher sets the rope loop in motion
Energy is shifted where charges the meet resistance in the circuit.	Energy is shifted by working where one of pupils grips the rope a little more tightly to provide a frictional force.

The rope loop teaching analogy

The teaching analogy allows the teacher to start talking through the electric circuit ideas in terms of familiar and concrete objects:

This familiar picture helps to bring meaning to the idea that:



The teaching analogy helps the pupils in two ways:

- It helps the pupils to visualise what is going on in the circuit.
- It provides the pupils with a set of simple ideas to think with.

With these points in mind, you should encourage the pupils to talk and think with the teaching analogy and to develop an electric circuit model, wherever possible.

The rope loop teaching analogy

Now it's obvious that the rope isn't coming from me. I'm just making it move around. In just the same way, the charges don't come from the battery. It just makes them move around the circuit.

This may help pupils with Challenge 1.

Look everybody! As soon as I set the rope moving here, it starts moving all around the loop. In just the same way, as soon as the circuit is completed, the charges start moving in all parts of the circuit.

This may help pupils with Challenge 2.

The same amount of rope returns to me as leaves me. The rope doesn't get used up, or disappear, on the way round. In just the same way, the current doesn't get used up on the way around the circuit.

This may help pupils with Challenge 3.

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Working on the loop

Find out more about electrical working.

It is interesting to see that there are clear and direct parallels between the rope loop analogy and the electric circuit model set out in the Physics Narrative.

With the rope loop the teacher works on the rope to pull it through, a length at a time. At the same time, energy is shifted elsewhere in the loop due to the frictional force of a hand gripped on the rope. The pulling force applied by the teacher acts to keep the rope moving, whilst the frictional force applied by the pupil acts to resist the motion of the rope. Indeed we can say that the rope does work on the hand to warm it up. In exactly the same way we can say that the battery works on the loop of charges to keep them in motion, whilst at the same time the charges work on the ionic lattice in the bulb to heat it up.

With the rope loop energy is shifted through mechanical working whilst with the electric circuit we are dealing with electrical working (more detail on working as a pathway for shifting energy in the energy topic).