

Fully aligned
with the Australian
Curriculum

Circuits and switches

Year 6

Physical sciences



About this unit Circuits and switches

Access to safe, reliable electrical power has revolutionised our lives in countless ways. With a flick of a switch we complete a circuit, allowing electrical energy to be transferred and transformed into light in our lamps and televisions, heat in our toasters and electric blankets, sound in our radios, and motion in our dishwashers and blenders.

The *Circuits and switches* unit is an ideal way to link science with literacy in the classroom. Through hands-on investigations, students explore simple circuits and their components, including batteries, bulbs and switches to explain how a torch works. They discuss sources of electrical energy, and plan, make and appraise a model incorporating an electrical circuit with a switch.

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Foreword

Never has there been a more important time for science in Australia. More than ever, we need a scientifically-literate community to engage in debates about issues that affect us all. We also need imaginative thinkers to discover the opportunities in our exponentially expanding knowledge base. Teachers play a vital role in nurturing the minds of our future citizens and scientists.

The Australian Academy of Science has a long, proud history of supporting science education. Our primary education program, **PrimaryConnections**: linking science with literacy, now has over 15 years' experience in supporting teachers to facilitate quality learning experiences in their classrooms. Regular evaluations demonstrate the significant impact the program can have on both teacher confidence and student outcomes.

PrimaryConnections has been developed with the financial support of the Australian Government and endorsed by education authorities across the country. It has been guided by its Steering Committee, with members from the Australian Government and the Australian Academy of Science, and benefitted from input by its Reference Group, with representatives from all states and territories.

Key achievements of the program include engaging over 24,000 Australian teachers in professional learning workshops, producing multi award-winning curriculum resources, and developing an Indigenous perspective framework that acknowledges the diversity of perspectives in Australian classrooms.

The **PrimaryConnections** teaching and learning approach combines guided inquiry, using the 5Es model, with hands-on investigations. It encourages students to explore and test their own, and others', ideas and to use evidence to support their claims. It focuses on developing the literacies of science and fosters lasting conceptual change by encouraging students to represent and re-represent their developing understandings. Students are not only engaged in science, they feel that they can do science.

This is one of 40 curriculum units developed to provide practical advice on implementing the teaching and learning approach while meeting the requirements of the Australian Curriculum: Science. Trialled in classrooms across the country and revised based on teacher feedback, and with the accuracy of the teacher background information verified by Fellows of the Academy, the experience of many brings this unit to you today.

I commend **PrimaryConnections** to you and wish you well in your teaching.

Professor John Shine, AC Pres AA

President (2018–2022)

Australian Academy of Science

The PrimaryConnections teaching and learning approach

PrimaryConnections units embed inquiry-based learning into a modified 5Es instructional model. The relationship between the 5Es phases, investigations, literacy products and assessment is illustrated below:

PrimaryConnections 5Es teaching and learning model

Phase	Focus	Assessment focus
ENGAGE	Engage students and elicit prior knowledge	Diagnostic assessment
EXPLORE	Provide hands-on experience of the phenomenon	Formative assessment
EXPLAIN	Develop scientific explanations for observations and represent developing conceptual understanding Consider current scientific explanation	Formative assessment
ELABORATE	Extend understanding to a new context or make connections to additional concepts through a student-planned investigation	Summative assessment of the Science Inquiry Skills
EVALUATE	Students re-represent their understanding and reflect on their learning journey, and teachers collect evidence about the achievement of outcomes	Summative assessment of the Science Understanding

More information on PrimaryConnections 5Es teaching and learning model can be found at:
www.primaryconnections.org.au

Reference: Bybee, R.W. (1997). *Achieving scientific literacy: from purposes to practical action*. Portsmouth, NH: Heinemann.

Developing students' scientific literacy

The PrimaryConnections program supports teachers in developing students' scientific literacy. Scientific literacy is considered the main purpose of school science education and has been described as an individual's:

- scientific knowledge and use of that knowledge to identify questions, acquire new knowledge, explain scientific phenomena and draw evidence-based conclusions about science-related issues
- understanding of the characteristic features of science as a form of human knowledge and enquiry
- awareness of how science and technology shape our material, intellectual and cultural environments
- willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen

Reference: Programme for International Student Assessment & Organisation for Economic Co-operation and Development. (2009). *PISA 2009 assessment framework: key competencies in reading, mathematics and science*. Paris: OECD Publishing.

Linking science with literacy

PrimaryConnections has an explicit focus on developing students' knowledge, skills, understanding and capacities in science and literacy. Units employ a range of strategies to encourage students to think about and to represent science.

PrimaryConnections develops the literacies of science that students need to learn and to represent their understanding of science concepts, processes and skills. Representations in PrimaryConnections are multimodal and include text, tables, graphs, models, drawings and embodied forms, such as gesture and role-play. Students use their everyday literacies to learn the new literacies of science. Science provides authentic contexts and meaningful purposes for literacy learning, and also provides opportunities to develop a wider range of literacies. Teaching science with literacy improves learning outcomes in both areas.

Assessment

Science is ongoing and embedded in PrimaryConnections units. Assessment is linked to the development of literacy practices and products. Relevant understandings and skills are highlighted at the beginning of each lesson. Different types of assessment are emphasised in different phases:



Diagnostic assessment occurs in the *Engage* phase. This assessment is to elicit students' prior knowledge so that the teacher can take account of this when planning how the *Explore* and *Explain* lessons will be implemented.



Formative assessment occurs in the *Explore* and *Explain* phases. This enables the teacher to monitor students' developing understanding and provide feedback that can extend and deepen students' learning.




Summative assessment of the students' achievement developed throughout the unit occurs in the *Elaborate* phase for the Science Inquiry Skills, and in the *Evaluate* phase for the Science Understanding.

Rubrics to help you make judgments against the relevant achievement standards of the Australian Curriculum are available on our website:
www.primaryconnections.org.au



Safety

Learning to use materials and equipment safely is central to working scientifically. It is important, however, for teachers to review each lesson before teaching, to identify and manage safety issues specific to a group of students. A safety icon  is included in lessons where there is a need to pay particular attention to potential safety hazards.

The following guidelines will help minimise risks:

- Be aware of the school's policy on safety in the classroom and for excursions.
- Check students' health records for allergies or other health issues.
- Be aware of potential dangers by trying out activities before students do them.
- Caution students about potential dangers before they begin an activity.
- Clean up spills immediately as slippery floors are dangerous.
- Instruct students never to smell, taste or eat anything unless they are given permission.
- Discuss and display a list of safe practices for science activities.

Teaching to the Australian Curriculum: Science

The Australian Curriculum: Science has three interrelated strands—Science Understanding, Science as a Human Endeavour and Science Inquiry Skills—that together ‘provide students with understanding, knowledge and skills through which they can develop a scientific view of the world’. (ACARA, 2020).

The content of these strands is described by the Australian Curriculum as:

Science Understanding	
Biological sciences	Understanding living things
Chemical sciences	Understanding the composition and behaviour of substances
Earth and space sciences	Understanding Earth’s dynamic structure and its place in the cosmos
Physical sciences	Understanding the nature of forces and motion, and matter and energy
Science as a Human Endeavour	
Nature and development of science	An appreciation of the unique nature of science and scientific knowledge, including how current knowledge has developed over time through the actions of many people.
Use and influence of science	How science knowledge and applications affect people’s lives, including their work, and how science is influenced by society and can be used to inform decisions and actions
Science Inquiry Skills	
Questioning and predicting	Identifying and constructing questions, proposing hypotheses and suggesting possible outcomes
Planning and conducting	Making decisions about how to investigate or solve a problem and carrying out an investigation, including the collection of data
Processing and analysing data and information	Representing data in meaningful and useful ways, identifying trends, patterns and relationships in data, and using evidence to justify conclusions
Evaluating	Considering the quality of available evidence and the merit or significance of a claim, proposition or conclusion with reference to that evidence
Communicating	Conveying information or ideas to others through appropriate representations, text types and modes

 Above material is sourced from the Australian Curriculum: Australian Curriculum Assessment and Reporting Authority (ACARA). (2020). *Australian Curriculum: Science*. www.australiancurriculum.edu.au

Primary**Connections** has units to support teachers to teach each Science Understanding detailed in the Australian Curriculum: Science from Foundation to Year 6. Units also develop students’ skills and knowledge of the Science as a Human Endeavour and Science Inquiry Skills sub-strands, as well as specific sub-strands within the Australian Curriculum: English and Mathematics. Detailed information about its alignment with the Australian Curriculum is provided in each unit.

Unit at a glance

Circuits and switches

Phase	Lesson	At a glance
ENGAGE	Lesson 1 What makes it work?	To capture students' interest and find out what they think they know about how electrical energy can be transferred and transformed in electrical circuits and can be generated from a range of sources. To elicit students' questions about how electrical circuits work.
EXPLORE	Lesson 2 Get it to glow Session 1 Light it up! Session 2 Standard symbols	To provide students with hands-on, shared experiences of constructing and representing simple circuits.
	Lesson 3 Circuit scenarios	To provide students with hands-on, shared experiences of changing the different components in a circuit.
	Lesson 4 Make it go Session 1 Energy sources Session 2 The battery maker	To provide students with hands-on, shared experiences of different sources of energy that are used to generate electricity.
EXPLAIN	Lesson 5 In one direction	To support students to represent and explain their understanding of how electrical energy can be transferred and transformed in electrical circuits and can be generated from a range of sources. To introduce current scientific views
ELABORATE	Lesson 6 Switch it on!	To support students to plan and conduct an investigation of the function of switches in an electrical circuit.
	Lesson 7 Making models Session 1 Plan it Session 2 Make it	To support students to design, make and appraise a model that uses a circuit to transform energy from one form to another.
EVALUATE	Lesson 8 Present it!	To provide opportunities for students to represent what they know about how electrical energy can be transferred and transformed in electrical circuits and can be generated from a range of sources, and to reflect on their learning during the unit.

A unit overview can be found in Appendix 10, page 84.

Circuits and switches—Alignment with the Australian Curriculum

Circuits and switches is written to align to the Year 6 level of the Australian Curriculum: Science. The Science Understanding, Science Inquiry Skills, and Science as a Human Endeavour strands are interrelated and embedded throughout the unit (see page xii for further details). This unit focuses on the Physical sciences sub-strand.

Year 6 Science Understanding for the Physical Sciences:	Electrical energy can be transferred and transformed in electrical circuits and can be generated from a range of sources (AUSSSU097)
Incorporation in <i>Circuits and switches</i> :	Students generate inquiry questions about electrical circuits and their components. They discuss and formulate plans of action to answer these questions, including completing scientific investigations and generating new claims based on evidence to answer their questions. Investigations include building a simple electric circuit and conducting a fair test about the electrical conductivity of materials.

 All the material in the first row of this table is sourced from the Australian Curriculum.

Year 6 Achievement Standard

The Australian Curriculum: Science Year 6 achievement standard indicates the quality of learning that students should demonstrate by the end of Year 6.

By the end of Year 6, students compare and classify different types of observable changes to materials. They **analyse requirements for the transfer of electricity and describe how energy can be transformed from one form to another when generating electricity**. They explain how natural events cause rapid change to Earth's surface. They describe and predict the effect of environmental changes on individual living things. **Students explain how scientific knowledge helps us to solve problems and inform decisions and identify historical and cultural contributions.**

Students follow procedures to develop investigable questions and design investigations into simple cause-and-effect relationships. They identify variables to be changed and measured and describe potential safety risks when planning methods. They collect, organise and interpret their data, identifying where improvements to their methods or research could improve the data. They describe and analyse relationships in data using appropriate representations and construct multimodal texts to communicate ideas, methods and findings.

The sections relevant to *Circuits and switches* are bolded above. By the end of the unit, teachers will be able to make evidence-based judgments on whether the students are achieving below, at or above the achievement standard for the sections bolded above.

***Circuits and switches*—Australian Curriculum Key ideas**

In the Australian Curriculum: Science, there are six key ideas that represent key aspects of a scientific view of the world and bridge knowledge and understanding across the disciplines of science. The below table explains how these are represented in *Circuits and switches*.

Overarching idea	Incorporation in <i>Circuits and switches</i>
Patterns, order and organisation	Students explore, describe and sequence the components of an electric circuit to allow electrons to flow. They investigate what happens to a circuit when different materials are inserted and group the materials as insulators or conductors based on the patterns in their findings
Form and function	Students investigate the form and function of batteries and switches. They explore how modifications to the form of an electrical circuit affect its ability to function.
Stability and change	Students explore how the transformation of energy—in particular electrical energy—creates change in the world around them.
Scale and measurement	Students identify volts as the unit of measurement for the amount of ‘push’ a battery provides to the electrons in a circuit. They use an appropriate scale in their labelled diagrams to show the relative size of objects in their representations.
Matter and energy	Students investigate the transformation of energy from chemical reactions in batteries to electrical energy. This energy is transferred along the wires of the electric circuit to devices such as light bulbs that transform it into other energy types, such as light and heat.
Systems	Students investigate closed electrical circuits as systems providing a pathway for the continuous flow of electrons. They represent their understanding of electric circuit systems and the interdependence of its various components.

Circuits and switches—Australian Curriculum: Science

Circuits and switches embeds all three strands of the Australian Curriculum: Science. For ease of reference, the table below outlines the sub-strands covered in *Circuits and switches*, the content descriptions for Year 6 and their aligned lessons.

Strand	Sub-strand	Code	Year 6 content descriptions	Lessons
Science Understanding	Physical Sciences	ACSSU097	Electrical energy can be transferred and transformed in electrical circuits and can be generated from a range of sources	1–8
Science as a Human Endeavour	Nature and development of science	ACSHE098	Science involves testing predictions by gathering data and using evidence to develop explanations of events and phenomena and reflects historical and cultural contributions	2–5
	Use and influence of science	ACSHE100	Scientific knowledge is used to solve problems and inform personal and community decisions	3, 5
Science Inquiry Skills	Questioning and predicting	ACSYS232	With guidance, pose clarifying questions and make predictions about scientific investigations	2–7
	Planning and conducting	ACSYS103	Identify, plan and apply the elements of scientific investigations to answer questions and solve problems using equipment and materials safely and identifying potential risks	3, 7
		ACSYS104	Decide variables to be changed and measured in fair tests, and observe measure and record data with accuracy using digital technologies as appropriate	3, 7
	Processing and analysing data and information	ACSYS107	Construct and use a range of representations, including tables and graphs, to represent and describe observations, patterns or relationships in data using digital technologies as appropriate	1–8
		ACSYS221	Compare data with predictions and use as evidence in developing explanations	3, 7
	Evaluating	ACSYS108	Reflect on and suggest improvements to scientific investigation	7
	Communicating	ACSYS110	Communicate ideas, explanations and processes using scientific representations in a variety of ways, including multimodal texts	1–8

 All the material in the first four columns of this table is sourced from the Australian Curriculum.

General capabilities





The skills, behaviours and attributes that students need to succeed in life and work in the 21st century have been identified in the Australian Curriculum as general capabilities.


There are seven general capabilities and they are embedded throughout the units.

For further information see: www.australiancurriculum.edu.au

For examples of our unit-specific general capabilities information see the next page.

Circuits and switches—Australian Curriculum general capabilities

General capabilities	Australian Curriculum description	<i>Circuits and switches</i> examples
Literacy	Literacy knowledge specific to the study of science develops along with scientific understanding and skills. PrimaryConnections learning activities explicitly introduce literacy focuses and provide students with the opportunity to use them as they think about, reason and represent their understanding of science.	In <i>Circuits and switches</i> the literacy focuses are: <ul style="list-style-type: none"> • science journals • cutaway diagrams • TWLH charts • word walls • glossaries • circuit diagrams • biographies • factual texts • analogies • ideas maps • annotated diagrams • procedural texts.
 Numeracy	Elements of numeracy are particularly evident in Science Inquiry Skills. These include practical measurement and the collection, representation and interpretation of data.	Students: <ul style="list-style-type: none"> • collect, represent and interpret data through tables and diagrams.
Information and communication technology (ICT) competence	ICT competence is particularly evident in Science Inquiry Skills. Students use digital technologies to investigate, create, communicate, and share ideas and results.	Students are given optional opportunities to: <ul style="list-style-type: none"> • use interactive resource technology to view, record and discuss information.
 Critical and creative thinking	Students develop critical and creative thinking as they speculate and solve problems through investigations, make evidence-based decisions, and analyse and evaluate information sources to draw conclusions. They develop creative questions and suggest novel solutions.	Students: <ul style="list-style-type: none"> • use reasoning to develop questions for inquiry • formulate, pose and respond to questions about electrical circuits • give reasons to justify their responses to questions.
Ethical behaviour	Students develop ethical behaviour as they explore principles and guidelines in gathering evidence and consider the implications of their investigations on others and the environment.	Students: <ul style="list-style-type: none"> • ask questions of others, respecting each other's point of view.
 Personal and social competence	Students develop personal and social competence as they learn to work effectively in teams, develop collaborative methods of inquiry, work safely, and use their scientific knowledge to make informed choices.	Students: <ul style="list-style-type: none"> • work collaboratively in teams • conduct a role-play appropriately • follow procedural texts for working safely • participate in discussions.
 Intercultural understanding	Intercultural understanding is particularly evident in Science as a Human Endeavour. Students learn about the influence of people from a variety of cultures on the development of scientific understanding.	<ul style="list-style-type: none"> • Cultural perspectives opportunities are highlighted. • Important contributions made to science by people from a range of cultures are highlighted.

 All the material in the first two columns of this table is sourced from the Australian Curriculum.


Circuits and switches—Australian Curriculum: English

Strand	Sub-strand	Code	Year 6 content descriptions	Lessons
Language	Expressing and developing ideas	ACELA1524	Identify and explain how analytical images like figures, tables, diagrams, maps and graphs contribute to our understanding of verbal information in factual and persuasive texts	3, 5
	Phonics and word knowledge	ACELA1526	Understand how to use knowledge of known words, word origins including some Latin and Greek roots, base words, prefixes, suffixes, letter patterns and spelling generalisations to spell new words including technical words	1–8
Literacy	Interacting with others	ACELY1709	Participate in and contribute to discussions, clarifying and interrogating ideas, developing and supporting arguments, sharing and evaluating information, experiences and opinions	1–8
	Interpreting, analysing, evaluating	ACELY1712	Select, navigate and read texts for a range of purposes, applying appropriate text processing strategies and interpreting structural features, for example table of contents, glossary, chapters, headings and subheadings	5
		ACELY1713	Use comprehension strategies to interpret and analyse information and ideas, comparing content from a variety of textual sources including media and digital texts	5

 All the material in the first four columns of this table is sourced from the Australian Curriculum.


Circuits and switches—Australian Curriculum: Mathematics

Strand	Sub-strand	Code	Year 6 content descriptions	Lessons
Statistics and Probability	Data representation and interpretation	ACMSP147	Interpret and compare a range of data displays, including side-by-side column graphs for two categorical variables	3, 4
		ACMSP148	Interpret secondary data presented in digital media and elsewhere	5

 All the material in the first four columns of this table is sourced from the Australian Curriculum.

Circuits and switches—Australian Curriculum: Design and Technologies

Strand	Code	Year 6 content descriptions	Lessons
Knowledge and Understanding	ACTDEK020	Investigate how electrical energy can control movement, sound or light in a designed product or system	1–8
	ACTDEK023	Investigate characteristics and properties of a range of materials, systems, components, tools and equipment and evaluate the impact of their use	3–4, 6–8
Processes and Production Skills	ACTDEP024	Critique needs or opportunities for designing, and investigate materials, components, tools, equipment and processes to achieve intended designed solutions	8
	ACTDEP025	Generate, develop and communicate design ideas and processes for audiences using appropriate technical terms and graphical representation techniques	7, 8
	ACTDEP026	Select appropriate materials, components, tools, equipment and techniques and apply safe procedures to make designed solutions	8
	ACTDEP027	Negotiate criteria for success that include sustainability to evaluate design ideas, processes and solutions	7
	ACTDEP028	Develop project plans that include consideration of resources when making designed solutions individually and collaboratively	7

 All the material in the first four columns of this table is sourced from the Australian Curriculum.

Cross-curriculum priorities

There are three cross-curriculum priorities identified by the Australian Curriculum:

- Aboriginal and Torres Strait Islander histories and cultures
- Asia and Australia's engagement with Asia
- Sustainability.

Two of these are embedded within *Circuits and switches*, as described below.



Aboriginal and Torres Strait Islander histories and cultures

The Primary**Connections** Indigenous perspectives framework supports teachers' implementation of Aboriginal and Torres Strait Islander histories and cultures in science.

The framework can be accessed at: www.primaryconnections.org.au

Circuits and switches focuses on the Western science method of making evidence-based claims about energy, its sources (both renewable and non-renewable, and the way electrical energy is transferred between objects and transformed from one form to another.

Indigenous cultures might have different explanations for understanding energy, its sources and observed effects

Primary**Connections** recommends working with Aboriginal and Torres Strait Islander community members to access local and relevant cultural perspectives. Protocols for engaging with Aboriginal and Torres Strait Islander community members are provided in state and territory education guidelines. Links to these are provided on the Primary**Connections** website.

Sustainability

In *Circuits and switches* students discuss sources of electrical energy and investigate the ways electrical energy can be transferred and transformed in an electric circuit to operate devices that are useful to humans. This provides opportunities for students to develop an understanding that electrical energy used to make everyday devices work is produced from many different energy sources, and that some of these energy sources are renewable while others are non-renewable.

Students also develop an understanding that energy is neither created nor destroyed; that it can be stored and transformed to other forms of energy; that the amount of energy required to operate components such as light bulbs in a simple circuit varies; and that energy flow can be changed by using materials that help or prevent the flow of electrons. This can assist students to develop knowledge, skills and values for making decisions about individual and community actions that contribute to sustainable patterns of use of the Earth's energy resources.

Teacher background information

This information is intended as teacher information only. It provides teachers with information relevant to the science concepts so they can feel more confident and competent to teach each lesson. The content and vocabulary of this information is at a more detailed and advanced level than what is required for students.

Introduction to energy transfer and transformation

Energy is a commonly used but abstract term. We might refer to a food item as having a particular energy content measured in kilojoules or calories, speak about feeling energetic or refer to the rising costs of our energy bills. In physics, 'energy' has a very specific meaning: it is the capacity of a physical system to do work. Whenever a system changes, energy is at the heart of the change. It is transferred between objects (a rolling marble may knock another to cause it to start moving or transformed from one form to another, such as electrical energy to light or heat energy).

Energy cannot be created or destroyed: only transferred or transformed (nuclear reactions can transform mass into energy; however, this concept is not explored in this unit). The current concerns about reducing energy usage relate to the depletion of traditional non-renewable energy sources, such as coal, oil and gas. Once coal, oil or gas are burnt, much of the energy they originally contained is dissipated in the form of heat or light energy, either directly in the energy generation process or from the use made of that energy. The light and heat energy gradually spreads out in the atmosphere and into space. That energy is still present in the universe, but it is no longer useful for humans.

Energy can be stored. A good example of this is plants. Plants use energy in the form of sunlight to photosynthesise (convert light energy to chemical energy). They store this energy in complex sugars that can be used to make structures, such as wood, or to be used as 'food' at night when sunlight is not available. Plant consumers, for example, humans, can release this stored energy when they eat and metabolise the plant matter (or when they burn wood to release heat energy). It is this type of energy that is measured in kilojoules in our food. Electric batteries are also a good example of stored energy.

Energy can be transferred from one place to another. When it is stored, for example, in energy sources such as coal, oil, or gas, it can be physically transported by pipes, trucks or trains. Electrical energy is easily transferred through cables and wires between power stations and homes to appliances that require it. Other forms of energy can be transformed into electrical energy through the process of 'generating electricity'. The Sun, fossil fuels, wind and hydroelectric schemes are all important sources of energy that are used to generate electrical energy.

Circuits and switches

A circuit is a complete path of conductive material through which electricity flows. Electricity will not flow in a circuit that is not complete, so switches are introduced into circuits to allow us to easily control when the electrical current flows. The wires in our homes carry the electricity to appliances, which use a certain amount of electrical energy. If the appliance malfunctions, and too much electrical energy flows through the circuit, the fuse boxes in our homes protect us by breaking the circuit before the excess energy causes damage.

All materials are made of atoms. Atoms have a central core composed of protons (that have a positive charge and neutrons (that have no charge. This core is surrounded by a cloud of very small, negatively charged particles called electrons. In some materials, particularly metals, the outermost electrons can leave the cloud around their core and jump to others. This occurs in all the atoms in a piece of metal, creating a cloud of randomly moving electrons shared by all the atoms. This makes metals able to conduct electricity, and is also what gives metals their shimmer. The electrons in insulators cannot easily move away from their cores, which prevents them from conducting electricity.

When a source of electrical energy, such as a battery or a generator, is connected into a circuit, the electrons of the circuit start to move in a single direction rather than randomly. The electrons themselves move very slowly, measured in centimetres per minute. However, when you complete a circuit by switching on a light switch the light bulb begins to glow almost immediately. This is because the wires are already full of electrons, and so it is like a bicycle chain connected to the pedals of a bicycle. When you put pressure on the pedal, the wheel turns at once even though the chain links near the pedal have not yet reached the wheel. The source of electrical energy creates an electric field across the whole circuit, pushing all the loose electrons in the circuit to start moving at once.

Electrons can flow in either direction in standard wire, so it does not matter which way it is inserted in the circuit. However, some devices, such as batteries and LED light bulbs, have a positive and negative terminal. It is important to connect negative terminals to positive terminals so that electrons can flow through the circuit. This unit will use arrows in diagrams that represent electron flow. Conventional circuit diagrams, however, have arrows that represent a 'positive' current, which is marked as flowing in the opposite direction from the electrons. This unit focuses on electron flow, as it is easier for this age group to understand than the notion of current.

Note: In this unit, the terms 'battery' and 'cell' are used with the same meaning, as the term 'battery' is now in common usage. Technically, a 1.5V 'battery' is a cell, whereas a 'battery', for example, a car battery, is made of a set of cells.

Students' conceptions

Taking account of students' existing ideas is important in planning effective teaching approaches that help students learn science. Students develop their own ideas during their experiences in everyday life and might hold more than one idea about an event or phenomenon.

Many students have non-scientific ideas about batteries, circuits and electricity. The everyday meanings given to terms such as 'electricity', 'power', 'current' and 'energy' are often different from the way the scientific community uses them, and this can cause confusion.

Electricity is not 'current' or 'power' or 'energy'; it describes a range of phenomena associated with the presence and flow of electric charge. Electricity is associated with a wide array of everyday uses, which can lead to confusion. Therefore, in this unit we refer to electrical energy transferred via electrons flowing around a circuit.

To access more in-depth science information in the form of text, diagrams and animations, refer to the Primary**Connections** Science Background Resource, available on the Primary**Connections** website:

www.primaryconnections.org.au

Lesson 1 What makes it work?

AT A GLANCE

To capture students' interest and find out what they think they know about how electrical energy can be transferred and transformed in electrical circuits and can be generated from a range of sources.

To elicit students' questions about how electrical circuits work.

Students:

- create a cutaway diagram of how they think a torch works
- discuss what they know about electrical circuits and sources of energy.

ENGAGE

Lesson focus

The focus of the *Engage* phase is to spark students' interest, stimulate their curiosity, raise questions for inquiry and elicit their existing beliefs about the topic. These existing ideas can then be taken account of in future lessons.

Assessment focus



Diagnostic assessment is an important aspect of the *Engage* phase. In this lesson you will elicit what students already know and understand about how:

- electrical energy can be transferred and transformed in electrical circuits and can be generated from a range of sources.

Key lesson outcomes

Science

Students will be able to represent their current understanding as they:

- explain their existing ideas of how a torch works
- explain what they know about electrical circuits
- identify sources of energy.

Literacy

Students will be able to:

- use a cutaway diagram to display information
- record ideas on a TWLH chart
- participate in and contribute to discussions, sharing information, experiences and opinions.

This lesson also provides opportunities to monitor the development of students' general capabilities (highlighted through icons, see page xii).

Teacher background information

A torch is a simple and common example of an electrical circuit. A torch will not work until the switch is turned on. When a switch is turned on, it completes the electric circuit, making a complete path for the electrons to flow around. A torch works by having a fully connected path from one end of the battery (or batteries) to the light bulb, through the light bulb and back to the other end of the battery. In some torches, the torch case is part of the path or circuit. If the light bulb is broken it might have a disconnected wire, which means that there is no longer a circuit for electrons to flow through.

A battery is a store of energy. The energy is in the form of chemicals that can react with each other when the circuit is completed, transforming the stored chemical energy into electrical energy. Generally, a battery needs to be connected to a circuit in order for the chemical energy to be released. However, depending on the construction of the battery and how it is stored, some chemical reactions may still occur, which is why some batteries may go flat if left unused for a long period of time.

Energy is not produced from nothing, nor does it get used up and disappear. The store of chemical energy of the battery is gradually transformed to electrical energy, which is transferred to devices in the circuit that transform it into light, heat, sound or movement energy. An incandescent light bulb transforms the electrical energy into mostly heat and some light; an energy-efficient fluorescent light bulb or light-emitting diode (LED) transforms more of the electrical energy directly into light.

Equipment

FOR THE CLASS

- class science journal
- TWLH chart
- word wall
- battery-operated torch
- inside components of a torch (eg, wires, bulb, batteries)
- *optional*: old torches

FOR EACH STUDENT

- science journal

Preparation

- Read 'How to use a science journal' (Appendix 2).
- Read 'How to use a word wall' (Appendix 3).
- Source equipment required for Lesson 4 Session 1 (eg, 1 buzzer and 1 motor per team).
- Read 'How to use a TWLH chart' (Appendix 6). Prepare a four column chart for the class with the following headings:

Circuits and switches TWLH chart

	What we Think we know	What we Want to learn	What we Learned	H ow we know
How energy is transferred and transformed in an electrical circuit				
Sources of energy used to generate electricity				

- *Optional:* Display the class science journal and TWLH chart in a digital format.

Lesson steps

- 1 Introduce the inside components of a torch. Ask students what they think each could be used for.
- 2 Introduce the class science journal and discuss the purpose and features of a science journal.

Literacy focus


Why do we use a science journal?

We use a **science journal** to record what we see, hear, feel and think so that we can look at it later to help us with our claims and evidence.

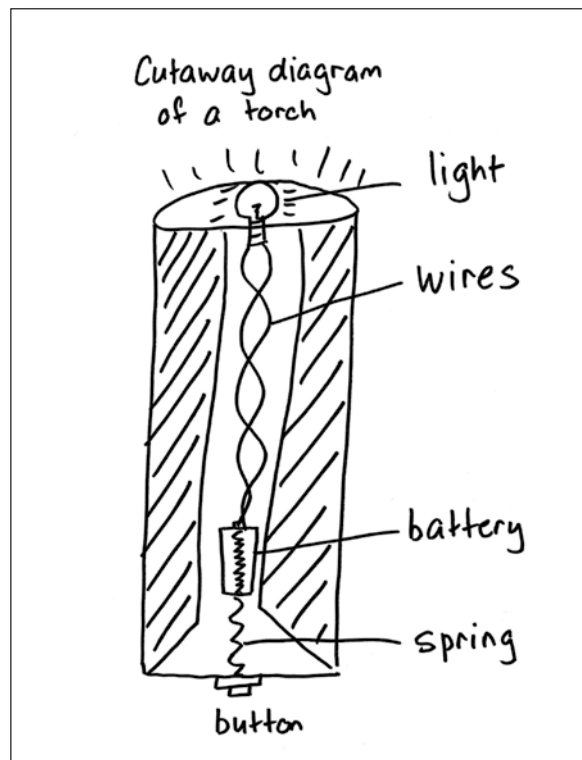
What does a science journal include?

A **science journal** includes dates and times. It might include written text, drawings, measurements, labelled diagrams, photographs, tables and graphs.

Record students' thoughts in the class science journal.

- 3 Explain that students are going to learn about electrical circuits in order to create a battery-operated model at the end of the unit. Brainstorm with students the kinds of things that a battery-operated model could do. Record students' thoughts in the class science journal.
- 4 Introduce the battery-operated torch and explain that students will be studying it in order to better understand how electrical circuits work and what electrical energy is used for.
- 5  Ask students to draw a cutaway diagram of a torch in their science journals, showing what they think they know about how all the internal parts work, including the switch, and how they are connected. Discuss the purpose and features of a cutaway diagram.

Optional: Show students different examples of cutaway diagrams (not a torch), such as a cutaway diagram of the Earth, a volcano or the human body.



Student work sample of a cutaway diagram of a torch

Literacy focus

Why do we use a cutaway diagram?

We use a **cutaway diagram** to show the inside and outside parts of an object.

What does a cutaway diagram include?

A **cutaway diagram** includes a title and a drawing showing what the inside of the object looks like. It includes labels with lines or arrows to indicate the feature.



- 6 Reassure students that they need not be anxious if they are unsure about how the torch works or what it looks like inside. Explain that the purpose of the diagram is to help students, and yourself, identify what they think they know before starting their learning journey. Ask students to include their thoughts about the following questions:

- What does a torch create?
- What is inside a torch?
- How do those parts help the torch to work?
- What does the switch do? How does it work?

Optional: Provide old torches for students to pull apart and observe.

Note: In the *Engage* phase, do not provide any formal definitions or correct students' answers as the purpose is to elicit students' prior knowledge.

- 7 As a class, discuss students' diagrams and annotations. Encourage students to discuss their reasons for their thinking, asking questions such as:
- What can you tell us about your diagram?
 - Why do you think that?

Ask students to discuss each other's thoughts respectfully and encouragingly. Explain that it is important to find out what you think you know and test it in order to learn, and that it is everyone's responsibility to make the class a safe environment to discuss ideas.

- 8 Introduce the TWLH chart (see 'Preparation'). Discuss its purpose and features.

Literacy focus

Why do we use a TWLH chart?

We use a **TWLH chart** to show our thoughts and ideas about a topic before, during and after an investigation or activity.

What does a TWLH chart include?

A **TWLH chart** includes four sections with the headings: What we **T**hink we know, What we **W**ant to learn, What we **L**earned, and **H**ow we know. Words or pictures can be used to show our thoughts and ideas.

- 9 Record students' thoughts about how electrical circuits transfer and transform energy in the 'What we **T**hink we know' column of the TWLH chart. Ask questions such as:
- How could we test that idea?
 - What do you think would happen if...?
- 10 Ask students where the electrical energy in a circuit comes from (the battery). Discuss how electrical energy in the home can also be delivered from power stations to our power points. Ask students what sources of energy they think power stations use to create electrical energy. Record students' ideas in the next row of the 'What we **T**hink we know' column of the TWLH chart.
- 11 Ask students what questions they might have about electrical circuits and energy sources. Record students' questions in the 'What we **W**ant to learn' column of the TWLH chart.

	What we Think we know	What we Want to know	What we Learned	How we know
How energy is transferred and transformed in an electrical circuit	<ul style="list-style-type: none"> The wires are connected to the battery and the globe. When you push the button it sends something to the batteries to light it up. There is stuff inside batteries that flow into wires. 	<ul style="list-style-type: none"> How to make a circuit? How does energy change form? Can you improve a circuit? How does electricity move around? 		
Sources of energy used to create electricity	<ul style="list-style-type: none"> solar sun gas oil heat light batteries fossil fuel - coal 	<ul style="list-style-type: none"> How does wind get transferred into electricity? How does the sun make electricity? How do batteries release energy? 		

Example of class TWLH chart at end of Lesson 1

- 12 Introduce the word wall. Discuss its purpose and features.

Literacy focus

Why do we use a word wall?

We use a **word wall** to record words we know or learn about a topic. We display the **word wall** in the classroom so that we can look up words we are learning about and see how they are spelled.

What does a word wall include?

A **word wall** includes a topic title or picture and words which we have seen or heard about the topic.

- 13 Ask students what words from today's lesson would be useful to place on the word wall.

Curriculum links

Science

- Compare the internal components of different types of torches.

Lesson 2 Get it to glow

AT A GLANCE

To provide students with hands-on, shared experiences of constructing and representing simple circuits.

Session 1 Light it up!

Students:

- construct and test different arrangements of a circuit.

Session 2 Standard symbols

Students:

- use symbols to draw a circuit diagram.

EXPLORE

Lesson focus

The *Explore* phase is designed to provide students with hands-on experiences of the science phenomenon. Students explore ideas, collect evidence, discuss their observations and keep records, such as science journal entries. The *Explore* phase ensures all students have a shared experience that can be discussed and explained in the *Explain* phase.

Assessment focus



Formative assessment is an ongoing aspect of the *Explore* phase. It involves monitoring students' developing understanding and giving feedback that extends their learning. In this lesson you will monitor students' developing understanding of how:

- electrical energy can be transferred and transformed in electrical circuits.

You will also monitor their developing science inquiry skills (see page xi).

Key lesson outcomes

Science

Students will be able to:

- make predictions about circuits that will light a light bulb
- construct and test circuits and record their observations
- compare their representations of circuits.

Literacy

Students will be able to:

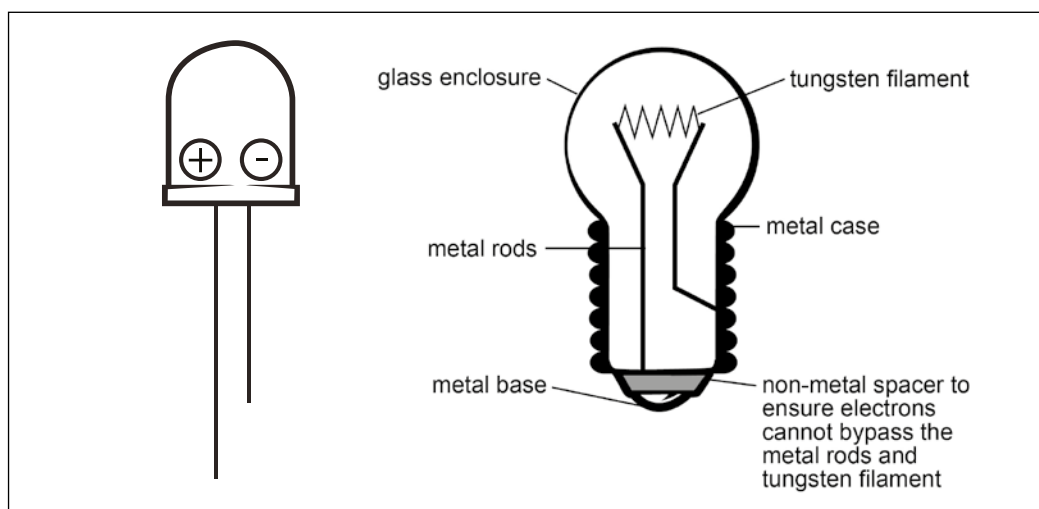
- use writing, drawing and modelling to record predictions, observations and explanations about circuits
- represent a circuit diagram using symbols
- record ideas on a TWLH chart
- participate in and contribute to discussions, sharing information, experiences and opinions.

This lesson also provides opportunities to monitor the development of students' general capabilities (highlighted through icons, see page xii).

Teacher background information

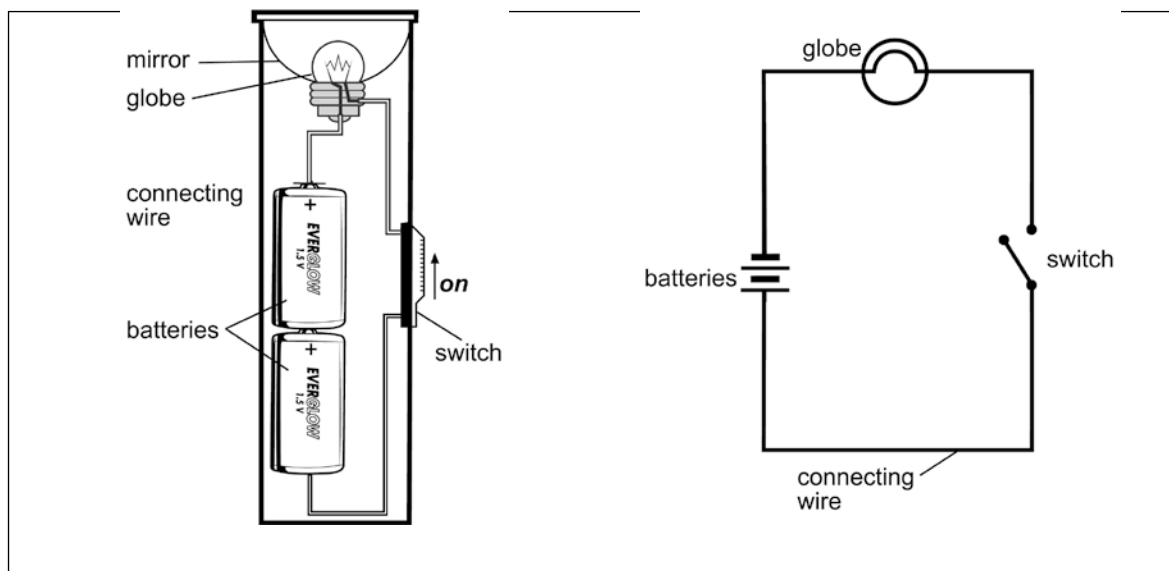
The main components of a torch circuit include a battery (or batteries, connecting wires, a switch and a light bulb. A circuit is a path for electrons to follow, which starts at one end of the battery and ends at the other. Electrons travel easiest along conductors such as wires. The metallic case of a torch is often used as a wire in a torch circuit. A switch is simply a device that either connects two wires or keeps them apart. When a switch is 'on' the electrons have a path through the switch, when the switch is 'off' the path is broken and the wires are not connected. Most older torches have incandescent lamps, with a filament enclosed in a glass shell. The incandescent bulb has a very thin piece of wire (the filament that heats up white hot when electrons move through it. The glass around the filament has had the air removed, which keeps the filament from burning up and protects fingers

When the battery is inserted in the torch, and the switch is turned on there is a complete path, or circuit, and the electrons can flow from the negative terminal of the battery around the circuit to the positive terminal. When the switch is closed (the 'ON' position, the electrons in the circuit start moving in a single direction (rather than randomly as before from the negative terminal of the battery towards the positive terminal through the metal of the wires, switch and lamp filament. An incandescent lamp will work no matter which direction the electrons go through it. Some newer torches have LED light bulbs, which have positive and negative terminals, and will only work when the electrons flow through in a particular direction.



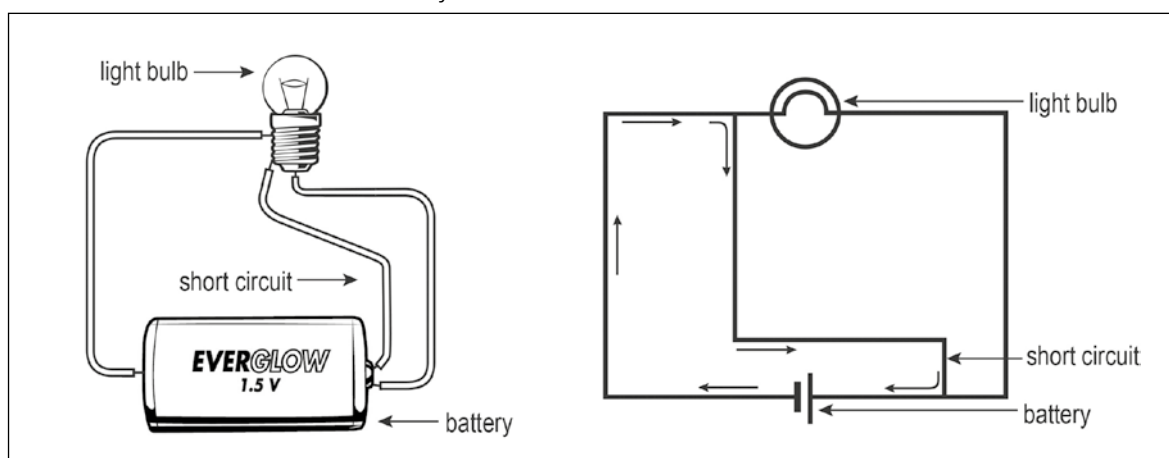
Positive and negative terminals on common lights used in torches

When you complete a circuit by turning on a switch, the light turns on very quickly. The light will come on before the electrons from the battery reach the lamp. When the switch is turned on, the battery causes all of the electrons in the wires to begin to move, rather like when you press on the pedals of a bicycle. The wheel starts to turn before the part of the chain near the pedal gets to the wheel. The whole chain moves as a unit, similar to what the electrons are doing in the circuit.

**Labelled diagram of the parts of a torch****Circuit diagram of a torch**

When a battery's positive and negative terminals are connected by the wires, switch, and lamp in a circuit, the chemicals within it react, transforming the chemical energy into electrical energy and causing the electrons to move around the circuit. If the terminals are connected to each other directly through a material with high conductivity, for example, a wire, the chemicals in the battery will react very quickly, causing a high flow of electrons through the circuit. The chemical energy is released very quickly, often causing the battery to become warm. The high flow of electrons may also cause the wire to become very warm and possibly even burn through.

A flashlight battery is very low voltage, typically 1.5v, and cannot cause an electrical shock. (It takes about 40V to cause an electrical shock through the skin. It can, however, release enough energy to burn through a thin wire, or exhaust the energy of the battery if it is connected directly from the positive end of the battery to the negative end. A direct path from the positive to the negative end of the battery is called a 'short circuit'. It is possible that when connecting the wires to the battery the students will see sparks, particularly if they make a short circuit. These sparks are caused by tiny pieces of metal from the surfaces which become very hot and shoot off. They are not dangerous, but it is a sign of a short circuit, and the wires should be disconnected before they overheat and drain the batteries.

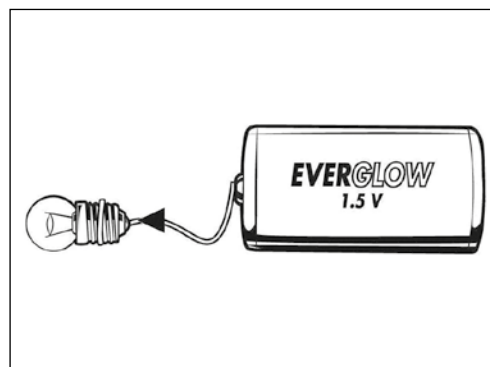
**Labelled diagram of a short circuit****Circuit diagram of a short circuit**

Note: You will need to monitor the circuits trialled by students because if they inadvertently create a short circuit they will quickly exhaust the store of the chemical energy in the batteries.

Students' conceptions

Source-sink model (non-scientific idea)

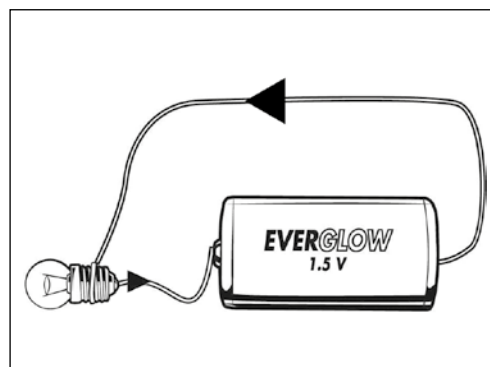
Students might believe that batteries push something to the light bulb, which is transferred through the wire. This might mean that they only believe one wire is needed, whereas a complete circuit is required for the battery to operate and for the electrons of the circuit to move in a single direction. This conception is reinforced by the fact that it appears that home appliances only need one cord to connect to mains power, however, the cord has several wires embedded to complete the circuit.



Note: The arrows in the models in this unit represent electron flow. Arrows in conventional circuit diagrams represent current, which is marked as flowing in the opposite direction. This unit focuses on electron flow, as it is easier for this age group to understand than the notion of current.

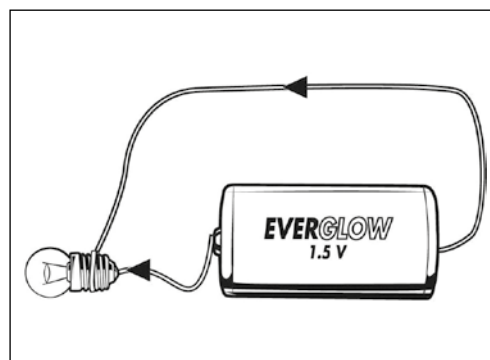
Consumption model (non-scientific idea)

Students correctly identify that two connection points are required. But they think that something comes out of the battery, which is partially (or totally) used up by the light globe so less returns to the battery. The number of electrons in each wire does not change, although the electrons themselves move. What is consumed is the chemical energy in the battery, which is released when hooked into a circuit and converted (transformed) by the bulb into light (and sometimes heat).



Clashing currents model (non-scientific idea)

Students might think that things flow from each end of the battery and meet in the devices on the circuit. The collision of these two streams of things creates light (and sometimes heat). This 'clashing currents' model can mean that students correctly identify that two connection points are necessary, but does not reflect the scientific understanding that the electrons of the circuit move in the direction from the negative terminal or the battery to the positive.



Unaware of positive and negative terminals

Students might be able to draw a circuit but not connect the wires in such a way as to make the light glow. One reason is that they might not realise that the electrons only flow in one direction from negative to positive terminals.

Reference for models: Osborne, R. & Freyberg, P. (Eds). (1985). "Learning in Science, the implications of children's science." Auckland, New Zealand: Heinemann Education, 23–4.

Session 1 Light it up!

Equipment

FOR THE CLASS

- class science journal
- team roles chart
- team skills chart
- TWLH chart
- word wall
- 1 enlarged copy of 'Light it up!' (Resource sheet 1)
- stripping pliers or knife, (see 'Preparation')
- spare light bulbs, batteries and wire

FOR EACH TEAM

- each team member's science journal
- role wristbands or badges for Director, Manager and Speaker
- 1 copy of 'Light it up!' (Resource sheet 1) per team member
- 1 battery (1.5V)
- 1 light bulb (1.5V) or LED
- 2 x 10 cm lengths of insulated wire, with ends stripped of insulation (see 'Preparation')

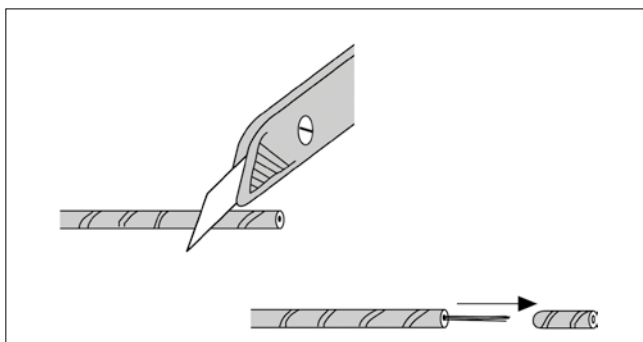
Note: While equipment such as light bulb holders and battery holders is available, using it can prevent students from seeing the connection points on a light bulb and a battery. Students might therefore believe that the holders themselves play some part in the circuit. During this lesson, it is preferable that students do not use light bulb or battery holders.

EXPLORE

Preparation

- Read 'How to organise collaborative learning teams' (Year 3–Year 6) (Appendix 1). Display an enlarged copy of the team skills chart and the team roles chart in the classroom. Prepare role wristbands or badges.
- Prepare an enlarged copy of 'Light it up!' (Resource sheet 1).
- Using stripping pliers, strip the insulation from both ends of the pieces of wire. If using a knife, strip the ends as shown.

Note: This must be done by the teacher or another adult, not by students.



Stripping insulation from the ends of the wire

- *Optional:* Display 'Light it up!' (Resource sheet 1) in a digital format.

Lesson steps

- 1 Review the previous lesson, focusing on students' ideas of how a torch works.
- 2 Explain that students will be working in collaborative learning teams to explore different arrangements of the battery, wire and bulb that will make the bulb light up.
- 3 Introduce the enlarged copy of 'Light it up!' (Resource sheet 1). Explain each step of the Predict, Reason, Observe and Explain (PROE) strategy.
- 4 Explain that students will draw the arrangements they predict will work and then record their reasons for why they think that. Explain that students will then share their predictions and explanations with their team.
- 5 Explain that teams will then construct and test the arrangements, and then complete the 'O' and 'E' sections of the 'Light it up!' (Resource sheet 1).
- 6 Draw students' attention to the equipment table and discuss its use. Explain that this table is where Managers will collect and return equipment.

Note: Explain that when using low-voltage batteries, for example, 9V or less, in their investigation, it is safe for students to touch bare wire because there is only a small amount of electrical energy coming from the battery. Any bare wires carrying mains electricity or high voltage (electrical energy) are extremely dangerous.



- 7 Form teams and allocate roles. Allow time for teams to complete the activity. If students are using collaborative learning teams for the first time, introduce and explain the team skills chart and the team roles chart. Explain that students will wear their role wristbands or badges to help them (and you) know which role each team member should be doing.



- 8 Record teams' observations and explanations in the class science journal. Ask questions, such as:

- What do you think each component of the circuit does?

- 9 Update the TWLH chart and word wall with words and images.

PrimaryConnections[®] Circuits and switches
Learning science with purpose

Light it up!

Name: _____ Date: _____
Other members of your team: _____

Predict
Draw simple diagrams of different arrangements of the battery, wire and bulb that you predict will light up.

①

wire
battery
bulb

②

bulb
wire
battery

Reason
Why do you think they will work? Because the power in the battery will go through the wire connected to the bulb and then the bulb will light up.

Observe
What happened? Which arrangement's lit up?
Nº 2 worked because the bulb lit up.

Explain
Did the results fit your prediction? Why do you think you observed what you did?
I think Nº1 didn't work because the wire needed to touch both ends of the battery which is what happened in Nº2.

Copyright © Australian Academy of Science, 2016. Resource sheet 1

Work sample of 'Light it up!' Resource sheet 1

Light it up!

Name: _____ **Date:** _____

Other members of your team: _____

Predict

Draw simple diagrams of different arrangements of the battery, wire and bulb that you predict will light up.

Reason

Why do you think they will work?

Observe

What happened? Which arrangement/s lit up?

Explain

Did the results fit your prediction? Why do you think you observed what you did?

Session 2 Standard symbols

Equipment

FOR THE CLASS

- class science journal
- team roles chart
- team skills chart
- TWLH chart
- word wall
- 1 enlarged copy of 'Light it up!' (Resource sheet 1)

FOR EACH TEAM

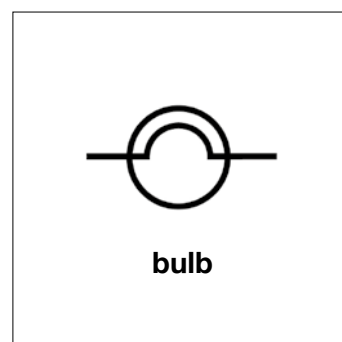
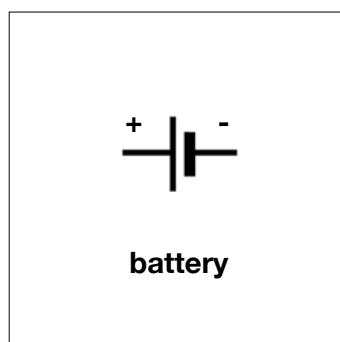
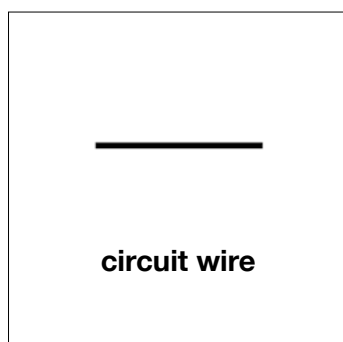
- each team member's science journal
- role wristbands or badges for Director, Manager and Speaker
- 1 copy of 'Light it up!' (Resource sheet 1) from previous session per team member
- *optional*: electrical symbol cards (see 'Preparation')

EXPLORE

Preparation

- Read 'How to use a glossary' (Appendix 4).
- Prepare a page in the class science journal as follows:

Standard electrical symbols



- *Optional*: Prepare cards of symbols for each team.
Note: For the battery symbol, the longer line represents the positive terminal. The symbol for the bulb does not differentiate positive and negative terminals, although in reality some bulbs, such as LEDs, may only be inserted in the circuit one way (positive terminal connected to the negative terminal of the battery and vice versa).
- *Optional*: Display 'Light it up!' (Resource sheet 1) and 'Standard electrical symbols' in a digital format.

Lesson steps

- 1 Review the previous session, focusing on students' diagrams of arrangements of components that made the bulb light up.



- 2 Introduce the term 'circuit' and discuss what it means in relation to the class exploration of lighting a light bulb. Discuss other meanings of the word 'circuit' that students know, such as a fitness circuit or a course or track used in racing.

Ask Speakers to share their team's results. Ask questions such as:

- What arrangements of the components made the light bulb glow?
- What did the arrangements that made the light bulb glow have in common?
- Why do you think those arrangements worked?

- 3 Explain to students that as the unit progresses, they will create a class glossary. Discuss the purpose and features of a glossary.

Literacy focus

Why do we use a glossary?

We use a **glossary** to provide definitions of technical terms that relate to a particular subject matter or topic.

What does a glossary include?

A **glossary** includes a list of technical terms in alphabetical order, accompanied by a description or an explanation of the term in the context of the subject.

Circuits and switches glossary	
A - D	E - H Electric circuit - a battery, bulb and wires that join together in a loop and make the bulb light up
I - L	M - P
Q - T	U - Z

Work sample of a glossary

- 4 Begin a glossary in the class science journal using the term 'electric circuit', for example, 'A battery, bulb and wires that join together in a loop and make the bulb light up.'
- 5 Discuss the confusion that could occur when using different ways to represent equipment, for example, some people draw different pictures to represent the same thing.

- 6 Explain that a way to show a circuit is by using a 'circuit diagram'. Explain that standard electrical symbols are used in circuit diagrams to represent how a circuit is connected.
- 7 Introduce and discuss the symbols used to represent the equipment students have used, such as wire, battery and light bulb (see 'Preparation').
- 8 Introduce the purpose and features of a circuit diagram.

Literacy focus

Why do we use a circuit diagram?

We use a **circuit diagram** to represent an electric circuit as a picture.

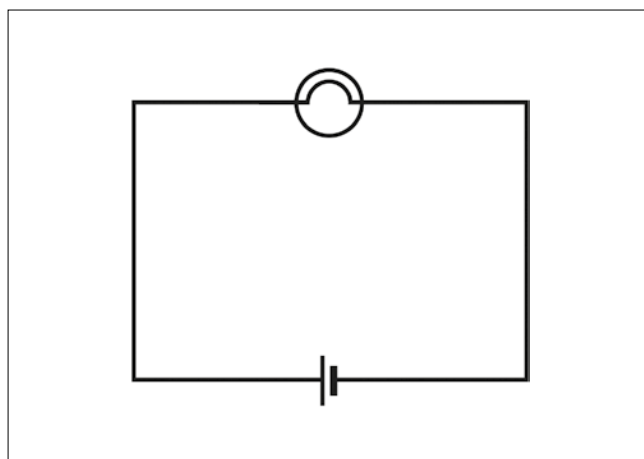
What does a circuit diagram include?

A **circuit diagram** includes standard symbols to represent the components of the electric circuit and shows their position in the circuit.

EXPLORE



- 9 Ask students to select one of the diagrams of a circuit that lit up the light bulb from 'Light it up!' (Resource sheet 1) and represent it in their science journals as a circuit diagram using electrical symbols.
- 10 Re-form teams. Allow time for teams to complete the activity.



Sample circuit diagram (wire, battery, light bulb)



- 11 Ask students to share their circuit diagrams with the class. Record teams' ideas in the class science journal.
- 12 Update the TWLH chart and word wall with words and images.

Curriculum links

Information and Communication Technology (ICT)

- Use a digital or online resources to construct circuit diagrams.

Technology

- Invite an electrician to visit the class to talk about how circuit diagrams are used in the workplace.

Lesson 3

Circuit scenarios

AT A GLANCE

To provide students with hands-on, shared experiences of changing the different components in a circuit.

Students:

- identify questions that can be investigated on the effects of changing different components in a circuit
- plan, conduct and evaluate a fair test investigation.

Lesson focus

The *Explore* phase is designed to provide students with hands-on experiences of the science phenomenon. Students explore ideas, collect evidence, discuss their observations and keep records, such as science journal entries. The *Explore* phase ensures all students have a shared experience that can be discussed and explained in the *Explain* phase.

Assessment focus



Formative assessment is an ongoing aspect of the *Explore* phase. It involves monitoring students' developing understanding and giving feedback that extends their learning. In this lesson you will monitor students' developing understanding of how:

- electrical energy can be transferred and transformed in electrical circuits.

You will also monitor their developing science inquiry skills (see page xi).

Key lesson outcomes

Science

Students will be able to:

- plan and conduct a fair test investigation
- record and analyse data
- provide evidence and reasoning to support claims.

Literacy

Students will be able to:

- complete a PROE on investigations
- record ideas on a TWLH chart
- participate in and contribute to discussions, sharing information, experiences and opinions.

This lesson also provides opportunities to monitor the development of students' general capabilities (highlighted through icons, see page xii).

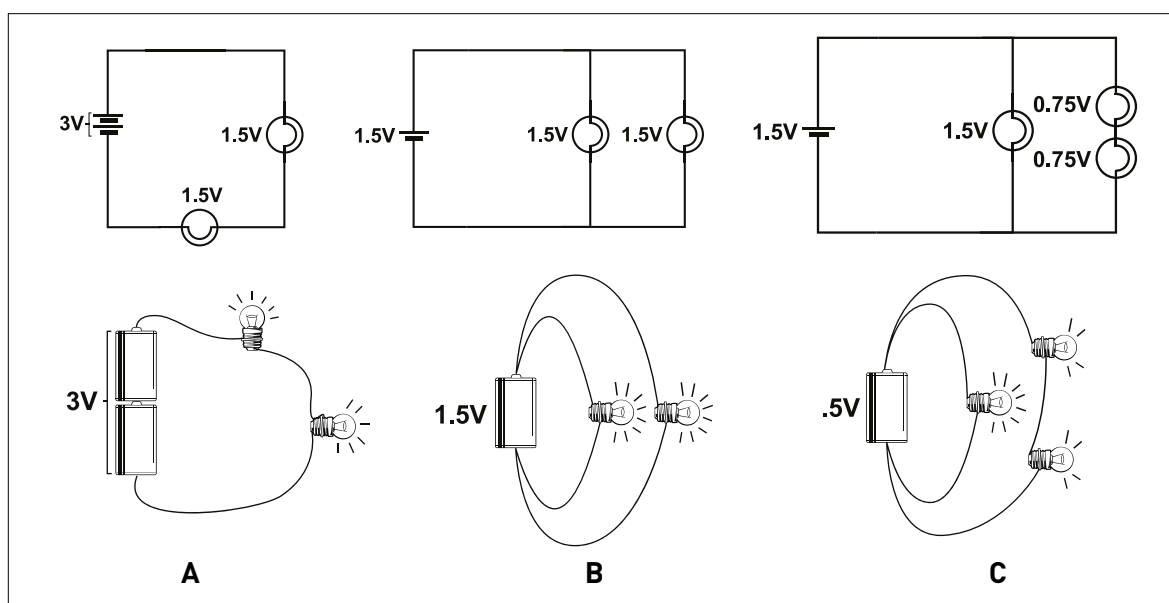
Teacher background information

A light bulb glows brightly when it receives enough electrical energy from its energy source. The battery voltage determines the amount of energy available for each electron. The electrical energy in a circuit is determined by the voltage of the energy source (energy per electron) and the current (number of electrons).

Placing batteries one after the other, with positive terminals next to negative terminals, increases the voltage available for the circuit: the total voltage is the sum of their voltages. Light bulbs are designed to work with a specific amount of voltage; 2V bulbs have smaller filaments than 6V bulbs and require less energy from the electrons to glow.

A 6V bulb needs to be connected to a circuit with a 6V battery, or four 1.5V batteries connected together. When a light bulb does not have enough voltage, then adding extra batteries to the circuit will make it glow more brightly. If it is receiving enough voltage, then adding more batteries could overload the bulb and cause it to burn out.

If you put two light bulbs in series then all the electrons will pass through both bulbs and the voltage (energy per electron) will be shared between them. If two 1.5V light bulbs are connected one after the other (in series) to a 1.5V battery, then they will each receive 0.75V worth of energy, which means that they will glow less brightly. Depending on the type of light bulb used, a small drop in voltage can make a big difference in terms of light produced.



Voltage in different types of circuits

Instead of adding light bulbs to an existing circuit (A), you can also create a new circuit directly connected to the same battery (B and C). That is called a parallel circuit. The advantage of connecting the bulbs that way is if one of the lights is disconnected the other lights will not be affected since the electrons still have a path to travel through from the negative terminal of the battery to the positive terminal. Our houses have many parallel circuits, so that you can turn on one light without having to turn on the TV and the microwave to complete the circuit.

A 1.5V battery will supply 1.5V to each complete circuit connected to it. Therefore, in figure B above, if each of the two parallel circuits has one 1.5V light bulb then they will both glow equally brightly (as brightly as a single bulb connected to a battery). However, the chemical energy in the battery will be converted more quickly so the battery will not last as long. If too many parallel circuits are drawing energy from the same source at the same time it may cause too much electron flow from the source, and overheat the wires. We have fuse boxes in our house to protect us from this.

Students' conceptions

If students have retained the 'consumption' model (see page 10), then they might think that less 'stuff' returns to the battery after going through the light bulb. If they connect light bulbs in series, they might think that the second bulb will receive less 'stuff' than the first one, and therefore the brightest bulb will be the closest to the battery and the lights will get progressively dimmer. However, all electrons start moving at the same time across the circuit and through the light bulbs, so they split the available voltage instantly.

Some students might think that the longer the wire the brighter the bulbs. If the wire is very long it might be harder for the electricity to flow through. However, generally modifying the length slightly does not make any appreciable difference to the brightness of the bulb.

Some students might think that bigger batteries are more powerful. Batteries come in different sizes: AAA, AA, C and D, but they are all as powerful as each other as they have the same voltage: 1.5V.

Equipment

FOR THE CLASS

- class science journal
- team roles chart
- team skills chart
- TWLH chart
- word wall
- 1 enlarged copy of 'Perplexing circuits' (Resource sheet 2)
- stripping pliers or knife (see 'Preparation')

FOR EACH TEAM

- each team member's science journal
- role wristbands or badges for Director, Manager and Speaker
- 1 copy of 'Perplexing circuits' (Resource sheet 2) per team member
- 3 light bulbs (1.5V)
- 3 batteries (1.5V)
- 6 x 10 cm lengths of insulated wire, with ends stripped of insulation
- self-adhesive tape
- 2 elastic bands

Preparation

- Read 'How to conduct a fair test' (Appendix 5).
- Read 'How to facilitate evidence-based discussions' (Appendix 7).
- Read 'How to write questions for investigation' (Appendix 8).

- Prepare an enlarged copy of 'Perplexing circuits' (Resource sheet 2).
- *Optional:* Display 'Perplexing circuits' (Resource sheet 2) in a digital format.

Lesson steps

- 1 Review previous lessons, focusing on the components and the arrangement of a working circuit.
- 2 Explain that in this lesson students will be exploring what happens to the brightness of the light bulb when they modify the circuit.

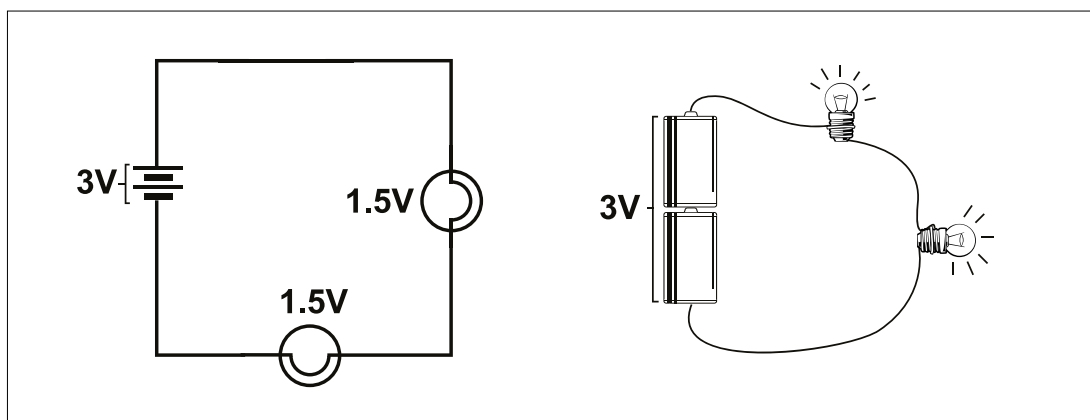


- 3 Ask students to suggest different variables that could be investigated, such as:

- length of wire
- number of wires
- number of bulbs
- number of batteries
- arrangement of bulbs and batteries.



Safety note: The voltage marked on bulbs is the maximum recommended voltage, so exceeding it might blow the bulb. If additional batteries are correctly added to a circuit then the circuit's total voltage is the sum of their individual voltages. If students wish to investigate the effect of the number of batteries ask them to use a circuit with three



Voltage divided in a series circuit

bulbs in series (as the voltage of the circuit is then divided among the bulbs).

- 4 Introduce the enlarged copy of 'Perplexing circuits' (Resource sheet 2). Ask students to complete the question for investigation with the variable they are modifying. Model recording what they think will happen (Predict) and why they think it will happen that way (Reason). Explain that if students are adding multiple bulbs to the circuit they should also explain for which bulb the prediction is.

PrimaryConnections[®]
Linking science with literacy

Circuits and switches

Perplexing circuits

Name: _____ Date: _____

Team members: _____

Question What happens to the brightness of the bulb when you change the number of batteries?






Predict: I predict that the more batteries that are added the brighter the bulb will glow.

Reason: More batteries means more electrical energy to make the bulb glow.

Observe: When we added more batteries the bulb blew.

Explain: There was too much voltage or electrical energy for the 1.5V bulb.

Work sample of 'Perplexing circuits' (Resource sheet 2)

- 5 Explain that teams will report back to the rest of the class on their findings, including presenting a claim with supporting evidence and reasoning.
-  6 Form teams and allocate roles. Ask Managers to collect equipment. Allow time for teams to conduct the investigation and record their results.
-  7 Ask Speakers to share their team's results with the class. Encourage students to question each other using the 'Science question starters' (see Appendix 7). Ask questions such as:
 - What did you predict would happen?
 - What did you observe?
 - Why was it different?
 - Why do you think that happened?
 - Why do you think that some teams' results were different?
-  8 Record teams' claims and evidence about circuits from their investigations in the L and H columns of the TWLH chart.
- 9 Discuss what happens to the other bulbs in the circuit when one of the bulbs has 'blown' or is disconnected without reconnecting the wires. Ask students why this happens and if the same thing happens in their home.
-  10 Ask teams to explore how to connect three bulbs to a series of batteries so that they continue to glow even if one is disconnected.
-  11 Ask teams to share their findings. Discuss how the battery supplies the same voltage to each parallel circuit, so the bulbs glow brightly but more electrical energy is used (see 'Teacher background information').
- 12 Update the word wall with words and images.

Perplexing circuits

Name: _____ Date: _____

Other members of your team: _____

Question What happens to the brightness of the bulb when you change

Predict:

Reason:

Observe:

Explain:

Question What happens to the brightness of the bulb when you change

Predict:

Reason:

Observe:

Explain:

Lesson 4 Make it go

AT A GLANCE

To provide students with hands-on, shared experiences of different sources of energy that are used to generate electricity.

Session 1 Energy sources

Students:

- survey devices for energy sources and transformations.

Session 2 The battery maker

Students:

- read and discuss a biography of Alessandro Volta
- read a factual text on how electrical energy is made.

EXPLORE

Lesson focus

The *Explore* phase is designed to provide students with hands-on experiences of the science phenomenon. Students explore ideas, collect evidence, discuss their observations and keep records, such as science journal entries. The *Explore* phase ensures all students have a shared experience that can be discussed and explained in the *Explain* phase.

Assessment focus



Formative assessment is an ongoing aspect of the *Explore* phase. It involves monitoring students' developing understanding and giving feedback that extends their learning. In this lesson you will monitor students' developing understanding of how:

- electrical energy can be generated from a range of sources.

You will also monitor their developing science inquiry skills (see page xi).

Key lesson outcomes

Science

Students will be able to:

- identify different energy transformations in a circuit
- identify different sources of energy
- understand that scientific explanations are revised as new evidence emerges.

Literacy

Students will be able to:

- read and summarise a biography
- read a factual text
- use a survey to collect information
- record ideas on a TWLH chart
- participate in and contribute to discussions, sharing information, experiences and opinions.

This lesson also provides opportunities to monitor the development of students' general capabilities (highlighted through icons, see page xii).

Teacher background information

Types of energy

Energy makes things work: it produces changes and makes things happen.

For primary school students, the following energy types can be considered:

- **Movement:** describes the motion of an object in time and space.
- **Electrical:** describes movement of electrons through wires, switches, bulbs, buzzers and motors.
- **Light:** describes electromagnetic radiation that can be detected by the retina in the eye.
- **Heat:** describes the speed at which particles in matter vibrate. The hotter something is, the more energy its particles have and the more vigorously they vibrate.
- **Microwaves:** describes electromagnetic radiation of high frequency and short wavelength that can cause particles such as water molecules to vibrate faster.
- **Sound:** describes waves of pressure, produced by vibrating objects travelling through solids, liquids or gases that our ears perceive as sound.
- **Elastic:** describes how certain materials stretch when they are stretched or compressed (have opposing forces applied) and store the applied energy. They have the ability to then spring back to their original shape, transforming stored energy to movement energy.
- **Gravitational:** describes how objects are attracted to other objects because of their large mass, such as a planet or the Sun. On Earth this means that objects that are not restrained in any way will drop towards the Earth's centre. Gravitational energy, as it is used here, is a measure relative to position. A book on a high shelf is said to have more 'gravitational' energy than one on a low shelf, since when it falls from the shelf, the higher one will gain more movement energy as it falls.
- **Chemical:** describes the fact that all chemicals have a certain amount of energy in the bonds that hold the atoms together. For example, complex carbohydrates and fats have lots of energy stored in the bonds between their atoms; bonds that animals and plants break down to release the energy.

- **Nuclear:** describes the energy released when the nuclei of atoms are split (fission) and or combined (fusion), and a tiny amount of their mass is converted directly to energy. Einstein's famous equation $E = mc^2$ describes this process. The Sun is a site of nuclear fusion, where hydrogen atom nuclei fuse to form a helium atom nucleus, releasing radiations of many types, including light, heat, ultraviolet and nuclear radiations. These are so energetic, they can burn skin and/or damage DNA.

Transfer and transformation of energy

Energy can be transferred (given from one thing to another), or transformed (changed from one type of energy to another type), but it cannot be created or destroyed. If we know where to look, and how to measure it, we can add up all of the energy (the total amount never changes).

An energy **transfer** is when the type of energy is the same, but the energy is given from one thing to another. For example, a golf ball sitting on the tee has no movement energy, but the swinging club about to hit it has a lot. Just after the ball is struck, the club is moving a little slower, and the ball is moving very fast. Some of the movement energy is **transferred** from the club to the ball, however, the total energy is the same.

Energy is **transformed** when it changes from one type of energy to another, for example, light energy from the sun is **transformed** to heat energy when it strikes a car parked in a sunny spot.

A wind turbine is an example of both energy transfer and transformation. The movement energy of the wind is **transferred** to the blades of the wind turbine, which is connected to an electrical generator. The electrical generator **transforms** the movement energy into electrical energy.

In a circuit, the battery contains chemicals which react with each other to **transform** chemical energy into electrical energy. Batteries are designed to **transform** the energy only when the positive and negative poles of the battery are connected to each other by a substance that allows electrons to flow, such as a metal wire. This allows the electricity to be transported to the motor. When a motor is connected to a battery so that the electrons flow through the motor, the electrical energy is **transformed** to movement energy. If a fan blade is attached to the motor the movement energy can be **transferred** to the surrounding air and produce wind.

Summary of energy sources that could be used to generate electricity

EXPLORE

Energy source	Description	Renewable?	Some considerations of environmental impacts
Fossil fuels	Fossilised remains of organic material, burned to release their stored chemical energy (originally from the Sun), eg, oil, coal, gas.	Yes, but it would take millions of years to re-create	<ul style="list-style-type: none"> Their combustion releases greenhouse gases and other pollutants. These gases were captured millions of years ago and are new additions to the atmosphere. Filtering systems are being developed to try to reduce some emissions. Attempts are being made to capture 'waste heat' to improve efficiency. The fuels need to be mined.
Biomass	Organic material, such as yard clippings, wood, or even municipal solid waste, burned to release stored energy	Yes	<ul style="list-style-type: none"> Their combustion re-releases greenhouse gases as well as other pollutants. Similar to fossil fuels, filtering systems might be developed Might promote land clearance and use of agricultural crops for energy production.
Nuclear fusion	Hydrogen atom nuclei combine to form a helium atom nucleus, emitting massive amounts of energy	No	<ul style="list-style-type: none"> We do not yet have a method of using this energy source directly; it is the reaction that occurs in stars, such as our Sun. Hydrogen is one of the most common elements in the solar system.
Nuclear fission	The nucleus of an atom, for example, uranium, is split forming two new nuclei releasing a huge amount of energy	No	<ul style="list-style-type: none"> The by products of these reactions are radioactive and dangerous to life forms. They need to be transported carefully and stored for very long periods of time (thousands of years) before they are safe to be handled). If damaged or not properly maintained, nuclear power plants can become the sources of large-scale radiation fallout or meltdowns. Uranium needs to be mined.
Geothermal	Capturing heat by pumping water through hot rock deep below the Earth's surface	Yes	<ul style="list-style-type: none"> Currently known environmental impacts are very small compared to other types of power generation.
Batteries	A chemical reaction transforms chemical energy into electrical energy when connected in a circuit	No	<ul style="list-style-type: none"> Batteries create waste products that are harmful to living things and need to be disposed of carefully. It also takes energy to make the metal electrodes and other components. Batteries are best for simply storing chemical energy. Rechargeable batteries can be used many times by running electrical current through them. This serves as a storage device for that electrical energy.
Wind and water	Wind and water movement harnessed to turn turbines	Yes, but not always available	<ul style="list-style-type: none"> Dams placed to regulate river flow can flood areas and disrupt river life. The placement of wind farms causes controversy and can harm some flying animals.
Sun	Light energy from the Sun captured through the use of solar panels	Yes, but not always available	<ul style="list-style-type: none"> The creation and upkeep of solar panels, particularly as they require many special metals.

Sustainable energy

The terms ‘alternative energy’, ‘renewable energy’ and ‘sustainable energy’ do not have strict definitions, but all have slightly different connotations and can be dependent on the context in which they are used. They can be described as follows:

- **Alternative energy** refers to any energy gained from resources that are intended to replace fuel sources with undesirable attributes and/or those that are currently predominately used.
- **Renewable energy** refers to energy that is taken from sources that can be replaced.
- **Sustainable energy** can be defined as the provision of energy that meets the needs of the present without compromising the needs of the future. Energy resources might be said to be sustainable if they can be replaced at the rate that they are used.

One area that needs to be taken into consideration when evaluating the sustainability of different forms of energy production is the materials and energy that are required to make the power plant, turbines or solar panels. Fossil fuels and uranium are extracted from the ground, as are the metals that make solar panels and wind turbines. It takes much more energy to produce a non-rechargeable battery than the amount of energy it contains. Solar panels used to require more energy than they produce, but modern techniques have been developed to make them more efficient and easier to make. Another consideration to take into account is how long the machines last and what happens to them when they are no longer useful.

Machines

Machines transform one type of energy into another. For example, a hair dryer transforms electrical energy into movement energy (moving air) and heat energy (which heats the air). A power station takes the energy from different sources in the environment, such as coal and running water, and transforms it into electrical energy. The mechanics of energy transformation are not discussed in this lesson, but it is essential to understand that machines transfer or transform energy. Home appliances are machines used in the home to accomplish specific tasks, such as cooking or cleaning. They use electrical energy to accomplish their tasks.

Students’ conceptions

Students might confuse energy with power. Energy is the capacity to do work, whereas power is a measure of how fast the work is done.

Students might think that energy can be created, for example, that energy is created by power stations. However, power stations and generators transform energy that is already present in wind and water (movement energy) or oil and coal (chemical energy) into electrical energy so that it can be easily distributed to our homes and appliances. Students might also believe that energy is fuel. Fuel is another name for an energy resource.

Students might think that energy can be destroyed or can disappear. However, energy is merely transformed into another form. For example, an electric heater transforms electrical energy into heat (and some sound and light). The heat gradually dissipates into the atmosphere. The energy has not disappeared but has been transformed into a form that is no longer useful for humans. The energy debate is not about depletion of energy, rather depletion of energy stored in useful forms.

Students might believe that only objects in motion have energy. Moving objects do have energy, but there are many other types of energy. For example, a book stored on a high shelf has more gravitational energy than a book stored on a low shelf. Both books have chemical energy that you could release by burning them.

Students might not hold concepts about stored forms of energy. We can store energy in a stretched elastic band or spring (elastic energy) because when released, the springs and elastic bands move back into their original position. An object up high has the potential to fall, and through falling converts its gravitational energy into movement energy.

Students might not think of their own bodies as ‘machines’ that require energy to do work. Every function carried out by our bodies, even the smallest involuntary action, requires energy that we metabolise from food. The chemical energy stored in the food is released and eventually transformed into the many forms of energy needed to carry out tasks, for example, the contraction of a muscle group when lifting an object.

Students might hold non-scientific ideas about energy transfer or transformation, thinking that each form of energy is an entity that is not related to other forms of energy, that is, that light is light and heat is heat, and they do not interact.

Session 1 Energy sources

Equipment

FOR THE CLASS

- class science journal
- team roles chart
- team skills chart
- TWLH chart
- word wall
- 1 enlarged copy of ‘Appliances survey’ (Resource sheet 3)
- 1 electric buzzer (3V)
- 1 electric motor (1.5V)
- 1 mobile phone
- stripping pliers or knife (see ‘Preparation’)

FOR EACH TEAM

- each team member’s science journal
- role wristbands or badges for Director, Manager and Speaker
- 1 copy of ‘Appliances survey’ (Resource sheet 3) per team member
- 1 electric buzzer (3V)
- 1 electric motor (1.5V)
- 2 batteries (1.5V)
- 1 light bulb (1.5V) or LED
- 3 x 10 cm lengths of insulated wire, with ends stripped of insulation

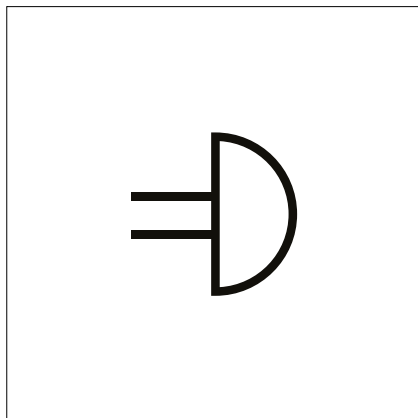
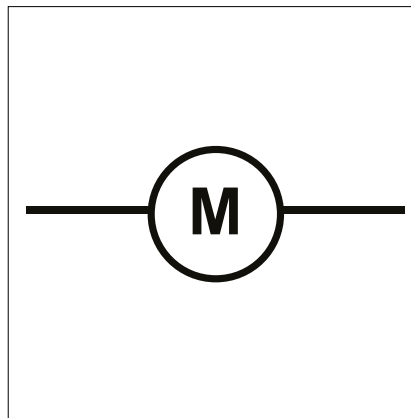
Preparation

- Prepare an enlarged copy of ‘Appliances survey’ (Resource sheet 3).
- Prepare a page in the class science journal as follows:

Types of energy

movement	heat	light	sound
electrical	chemical	elastic	gravitational
magnetic	nuclear		

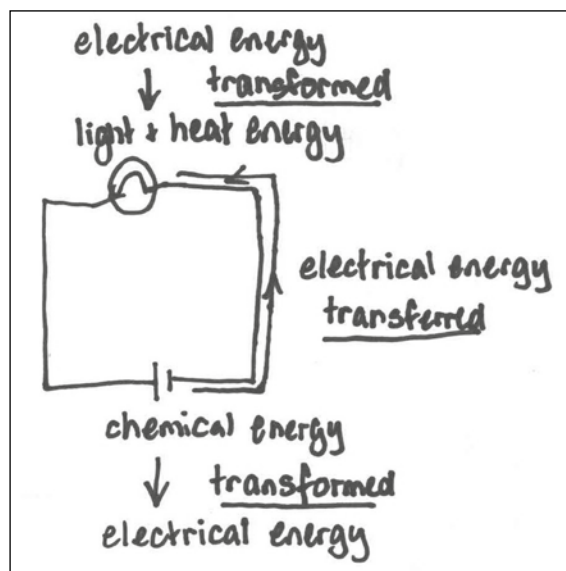
- Prepare the following description of energy in the class glossary: 'Energy makes things work: it produces changes and makes things happen'.
- Add the following symbols to the 'Standard electrical symbols' page in the class science journal:

**Buzzer symbol****Motor symbol**

- *Optional:* Display 'Appliances survey' (Resource sheet 3) in a digital format.

Lesson steps

- 1 Review the previous lesson, focusing on circuits and how changing the different components can affect the brightness of the bulb
- 2 Ask students why batteries are included in a circuit (they provide the source of energy). Show students the prepared description of energy in the class glossary (see 'Preparation'). Ask students to think of examples of where energy is used to make something work (energy is needed to make our legs work when we run, we need energy to heat water in a kettle).
- 3 Introduce the 'Types of energy' page in the class science journal (see 'Preparation'). Explain that it can be useful to think of energy in types. Discuss each one and the energy it represents.
- 4 Draw a simple circuit in the class science journal. Ask students to identify the energy types on the diagram, for example, the bulb produces light and heat energy. Discuss how the battery transforms chemical energy into electrical energy, which is transferred to the bulb where it is transformed again into light energy.



The 'transfer' and 'transformation' of energy in a simple circuit



- 5 Explain that energy is not created or destroyed: it is transferred or transformed. Add descriptions of 'transfer' and 'transform' to the class glossary. Ask students what they think happens when a battery goes flat. (The energy has not 'gone' or been 'used up'; all the stored energy of the battery has been transferred into other things.)

- 6 Ask students what they think of when they hear the word 'machine' and record a description in the class glossary. Introduce the scientific description of a machine as something that transforms one energy type to another, or transfers energy from one object to another.

- 7 Show students the buzzer and the motor. Discuss how these are simple machines (the same as a bulb).

- 8 Explain that students will work in their collaborative learning teams to explore placing the buzzer and the motor into a circuit. Ask students to draw the circuits that they create using circuit diagrams and add annotations about the energy types they have identified. Revise the purpose and features of a circuit diagram and introduce the standard images for a buzzer and motor in the class science journal (see 'Preparation').



- 9 Form teams and allocate roles. Ask Managers to collect equipment. Allow time for teams to conduct the investigation and record their results.



- 10 Ask Speakers to present their team's findings. Record a final version of the circuit diagrams in the class science journal.
- 11 Explain that teams will be looking for machines in the school that use electrical energy and identify what type or types of energy they produce.
Optional: Complete this as a home activity.
- 12 Introduce the enlarged copy of 'Appliances survey' (Resource sheet 3). Use a mobile phone as an example and discuss with students how to complete each section of the table to show sources and transformation of energy (mobile phone – battery – sound, light).
- 13 Explain that mains power is the term used to describe the electrical energy from a power station supplied to a building, like a house or school, and that we use that energy by plugging devices into a power point.

PrimaryConnections
Primary Science Connections

Circuits and switches



Appliances survey

Team members: _____ Date: _____

Appliance	Where does the electrical energy come from? Mains or battery?	Electrical energy is transformed into what other types of energy: heat, light, sound or movement?
mobile phone	battery	light & sound
computer	mains	light heat sound
fish pump	mains	sound movement
kettle	mains	heat sound light
remote control	battery	light heat
ipad	battery	light sound heat
refrigerator	mains	light sound heat movement
microwave	mains	light sound
electric blanket	mains	heat light
fan	mains	movement sound

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Work sample of 'Appliances survey' (Resource sheet 3)

-  **14** Re-form teams. Allow time for teams to complete the activity.
-  **15** Ask Speakers to present their team's results. Record responses in the class science journal.
- 16** Update the 'What we have **L**earned' section of the TWLH chart. Add words and images to the word wall.

Appliances survey

Team members: _____ Date: _____

Appliance	Where does the electrical energy come from? Mains or battery?	Electrical energy is transformed into what other types of energy: heat, light, sound or movement?

Session 2 The battery maker

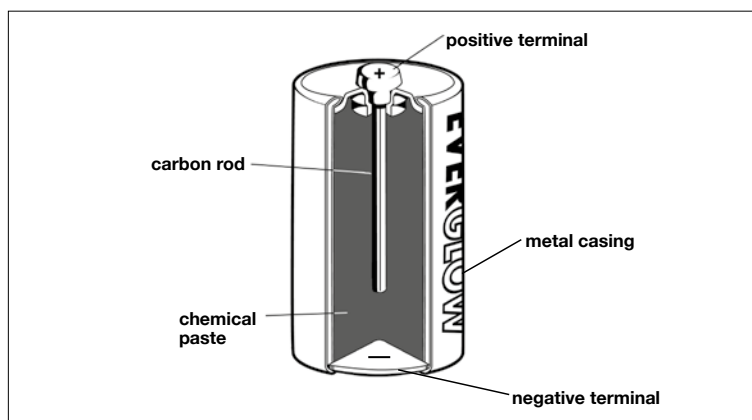
Teacher background information

Batteries

A battery is a device that stores chemical energy and makes it available in electrical form. We have evidence that batteries have been around for a very long time. Jars dated from about 200 B.C. are believed by archaeologists to have been used as a type of primitive battery.

Alessandro Volta's original cell battery, the voltaic pile, was developed in 1799. A voltaic pile is made of discs of two different metals, such as copper and zinc, separated with cloth soaked in a chemical solution. Volta's battery was the first continuous and reproducible source of an electrical current.

Batteries have two terminals generally made of different metals, separated by an electrolyte (a material that contains chemicals that react with the battery terminals to produce electricity). The electrolyte reacts with each metal in a different way, a chemical reaction occurs in the electrolyte, causing one metal to become 'electron rich', and the other to become 'electron poor'. This difference in charge drives electrons to flow from the 'electron rich' (negative terminal) to the 'electron poor' (positive terminal). When some of the electrons move from the negative terminal to the positive terminal (through an external circuit) the chemical reactions in the electrolyte continue and more electricity is produced.



Cutaway diagram of a battery



Safety note: Do not cut up lithium, alkaline or hydride batteries as this can be quite dangerous.

As the chemicals (mainly the zinc in the negative terminal) react, they are gradually used up. When this happens we say the battery is flat. Rechargeable batteries can reverse the chemical reaction when external electrical energy is applied in the opposite direction.

Note: Do not try to re-charge a non rechargeable battery. The battery can overheat and the corrosive chemicals may escape.

The voltage of the battery is the amount of energy (or 'push') that the battery can generate and give to the electrons. A typical torch battery has a voltage of 1.5V. By connecting batteries so that the positive side of one battery is connected to the negative side of the next, the voltages add together for the circuit: a 1.5V battery correctly connected to another 1.5V battery gives a total amount of $1.5V + 1.5V = 3V$ of energy. If two batteries are connected positive terminal to positive terminal then their voltages cancel out ($1.5V - 1.5V = 0V$).

A 4.5V battery (or series of three 1.5V batteries gives a bigger push than a 1.5V battery and can make a light glow brighter. Lamps are labelled with the biggest recommended voltage, as too much energy may make the lamp burn out.

Note: In this unit, the terms ‘battery’ and ‘cell’ are used with the same meaning, as the term ‘battery’ is now in common usage. Technically, a 1.5V ‘battery’ is a single cell, whereas a ‘battery’, for example, a car battery, is made of a set of cells.

How scientists think and work

Scientific knowledge is a set of explanations made by scientists based on observations and evidence. These explanations have been built up over time in an attempt to explain how the world works and continue to be revised as new evidence emerges.

Scientists conduct experiments in order to test ideas and find evidence. However, the conclusions and explanations drawn from the evidence can be influenced by the life experiences and beliefs of the scientists. Scientists are a part of the world they study and their ideas can be influenced by it

When scientists disagree, they first check the available information. In scientific publications, the authors clearly explain their experimental procedure so that the experiments can be replicated. Scientific debate is, however, generally about what conclusions can be drawn from the available evidence. The example given in this unit is the debate between Luigi Galvani (1737–1798 and Alessandro Volta (1745–1827 about the existence and nature of ‘animal electricity’ (see ‘Resource sheet 4’. Galvani made a frog’s leg twitch with electricity. When he saw a leg twitch under his scalpel without applying electricity, he concluded that frogs’ legs must produce electricity. Volta correctly pointed out that the dismembered frog’s leg did not produce electricity, and conducted experiments that showed that the electricity was produced due to the contact of two different metals in solution. Volta’s refusal to believe in animal electricity was, however, incorrect. The nerves of a living animal use chemical energy to produce a tiny amount of electric current to make muscles contract, and that is why the legs were contracting when a weak current went through them. The disagreement between Galvani and Volta led their followers to design very different experiments, advancing knowledge of electricity and nerve fibres.

Students’ conceptions

Some students might believe that the battery is a store of electrical energy (‘electricity’, ‘power’, ‘energy’, ‘amps’) that flows out of the battery to the light bulb, where it is used up. In fact, the battery does store something: it stores chemicals, which, when they react together, transform the chemical energy into electrical energy when it pushes the electrons around a circuit. This energy is not ‘used up’ by devices in the circuit, for example, a light bulb, but rather transformed or changed. There is less chemical and electrical energy after an incandescent light bulb has been powered but there is more light and heat energy in the room.

Students might think that the battery goes ‘flat’ when it has been emptied of electrical energy. Rather, it is when the chemicals inside the battery (for example, the zinc in ordinary batteries) have finished reacting with each other that the battery is exhausted and can no longer provide a ‘push’ to the electrons.

Equipment

FOR THE CLASS

- class science journal
- TWLH chart
- word wall
- 1 enlarged copy of 'Alessandro Volta: Battery maker' (Resource sheet 4)
- 1 enlarged copy of 'Energy sources' (Resource sheet 5)
- 1 collection of different-sized batteries

FOR EACH STUDENT

- science journal
- 1 copy of 'Alessandro Volta: Battery maker' (Resource sheet 4)
- 1 copy of 'Energy sources' (Resource sheet 5)

Preparation

- Prepare an enlarged copy of 'Alessandro Volta: Battery maker' (Resource sheet 4) and 'Energy sources' (Resource sheet 5).
- Collect batteries of different shapes and sizes, such as small watch batteries, AAA batteries, AA batteries, 9V square batteries and larger batteries.
- *Optional:* Display 'Alessandro Volta: Battery maker' (Resource sheet 4) and 'Energy sources' (Resource sheet 5) in a digital format.

EXPLORE

Lesson steps



- 1 Review the previous session, focusing on how machines use electrical energy from a battery or from the mains power to produce a variety of energy types.
- 2 Introduce the collection of different batteries (see 'Preparation'). Ask students questions such as:
 - When and why do we use batteries?
 - What would happen if batteries didn't exist?
 Record students' ideas in the class science journal.
- 3 Explain that students will read a biography to find out about a person who made an important contribution to the development of the battery. Introduce the enlarged copy of 'Alessandro Volta: Battery maker' (Resource sheet 4).
- 4 Discuss the purpose and features of a biography.

Literacy focus

Why do we use a biography?

We use a **biography** to describe events in a person's life. We can read a **biography** to find out about what a person did

What does a biography include?

A **biography** includes a title, dates and descriptions of the person's achievements. The events are usually listed in the order they occurred and include the person's contribution to society.

- 5 Read through and discuss 'Alessandro Volta: Battery maker' (Resource sheet 4). Add new words to the class glossary.



- 6 Discuss what the biography of Alessandro Volta suggests about the ways that scientists make or change their ideas. Ask questions such as:
- Why did the scientists disagree?
 - What was the first thing Volta did when he disagreed with Galvani? Why?
 - Did either of them change their ideas? Did they change other people's ideas?
 - What could have happened if Volta had agreed with Galvani?
- 7 Ask students what 'size' battery they have been using for the circuits (1.5V). Explain that the 'V' stands for volts and is named after Volta. Each battery is labelled with its voltage and this tells us about the 'push' it gives to make the current flow. For example, a 6V battery gives a bigger push than a 1.5V cell.
- 8 Ask students to add 'volts' to their glossaries.
- 9 Explain that chemical energy is just one means of producing electrical energy. Ask students what they think they know about how electrical energy is produced in power stations. Add this to the 'What we **Think** we know' column of the TWLH chart.
- 10 Introduce the enlarged copy of 'Energy sources' (Resource sheet 5). Discuss the purpose and features of a factual text.



Literacy focus

Why do we use a factual text?

We use a **factual text** to inform, teach or persuade someone reading it. We can read a **factual text** to collect information.

What does a factual text include?

A **factual text** includes a title, text and pictures. It might include labels, diagrams, maps and photographs.

- 11 Allow time for students to read their copy of 'Energy sources' (Resource sheet 5).
- 12 As a class discuss the information, asking questions such as:
- Where does electrical energy comes from?
 - What sources of energy would you like your energy to come from? Why?
- 13 Update the TWLH chart and word wall.



Curriculum links

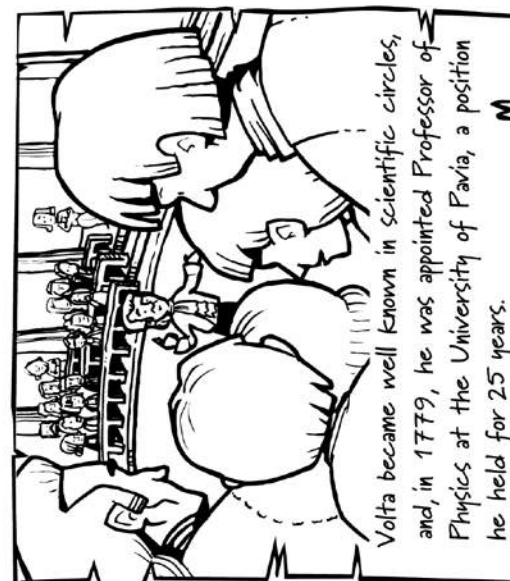
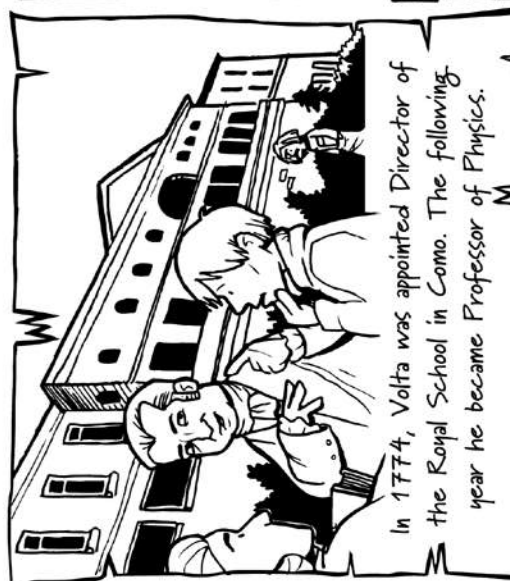
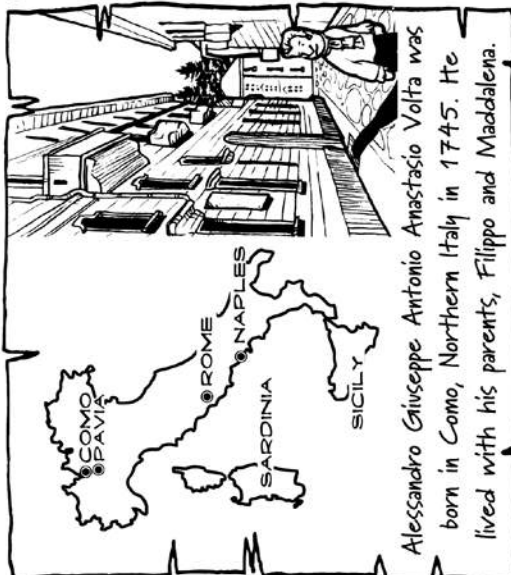
Science

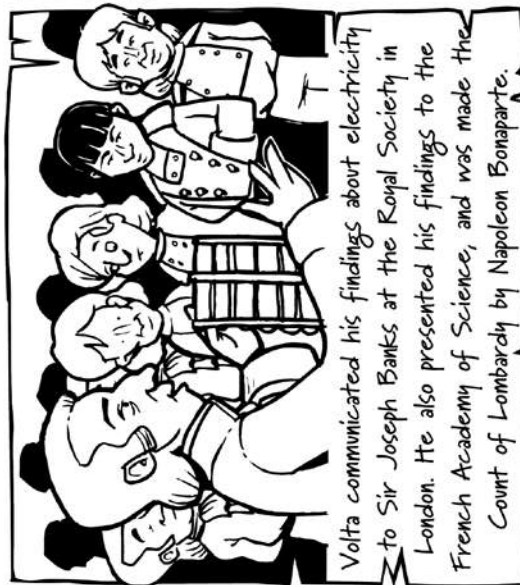
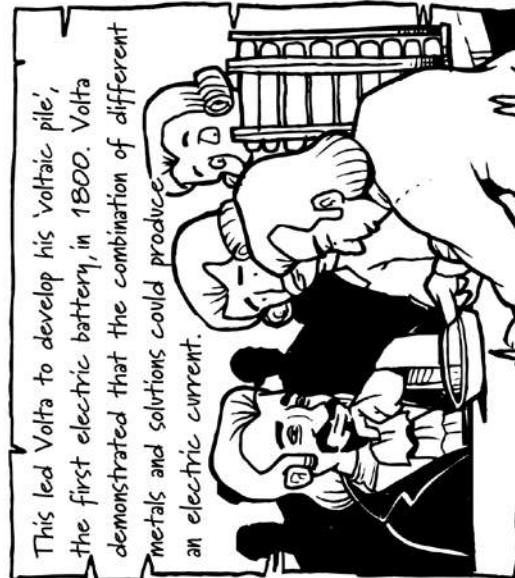
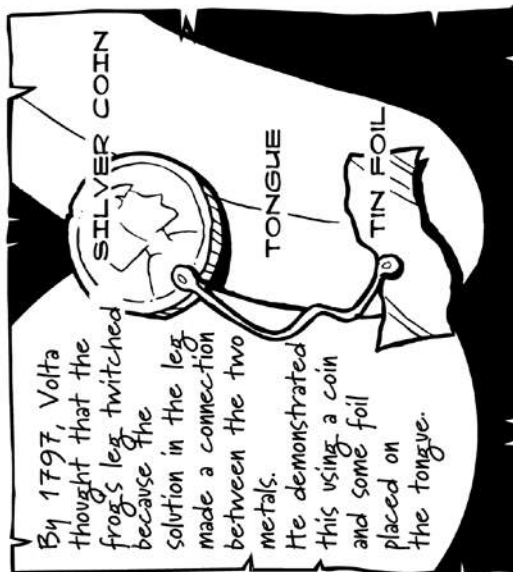
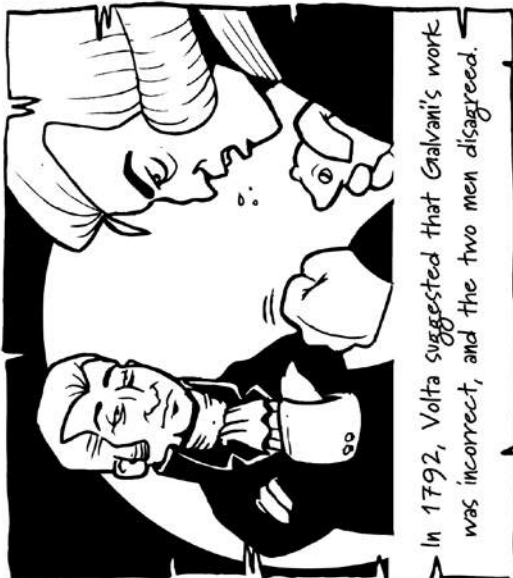
- Research further information about Volta and create a multimedia presentation about his life and research.
- Research the energy source that is used to generate electricity that you use in your school or home.

Alessandro Volta: Battery maker

Name: _____

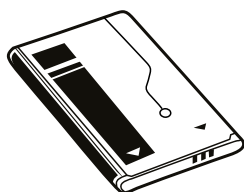
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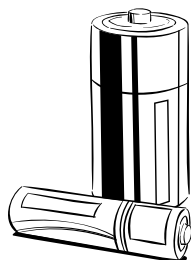


Energy sources

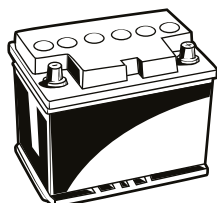
Batteries



Batteries provide electrical energy to many appliances that we use every day, including torches, mobile phones and toys. Without batteries we would have to plug these in every time we wanted to use them!



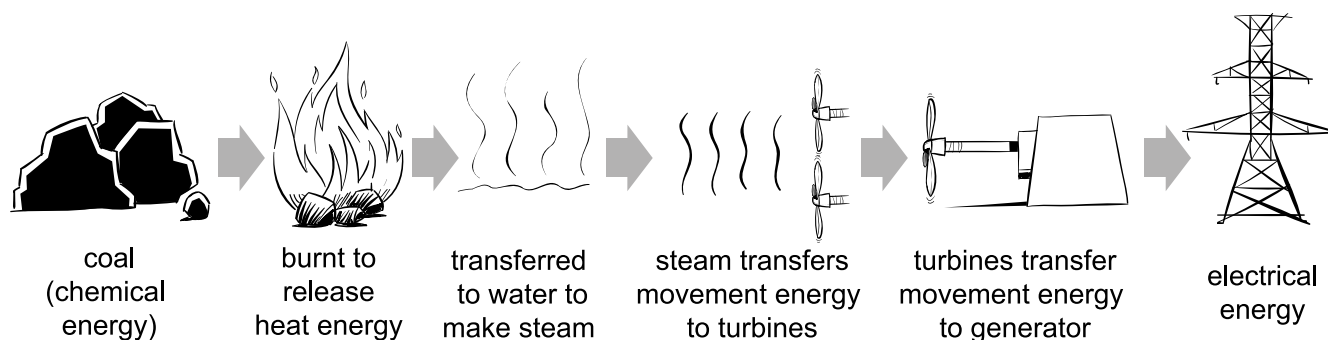
A battery contains chemicals that react together when the battery is connected to a circuit. This transforms chemical energy into electrical energy. The electrical energy is then transferred through the wires to the components that will transform it into many other types of useful energy, such as light bulbs, buzzers and movement.



As electrical energy is released the chemicals are changed and can no longer react together. This means that over time the battery 'goes flat'. Rechargeable batteries can reverse the reaction when plugged into mains powered battery chargers, using the electrical energy provided to re-create the chemicals.

Fossil fuels

Most of the electrical energy that we use is generated by power stations. Most power stations in Australia burn fossil fuels, usually coal, to generate electricity.

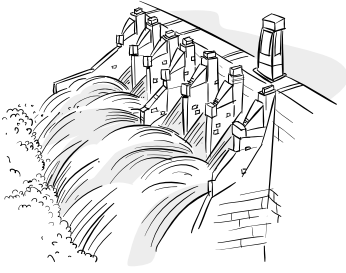


Flow chart of how coal is converted to electrical energy

Renewable forms of energy are being developed as alternative sources of heat energy to transform into electrical energy. These include liquid fuels made from plant material, for example, ethanol from sugarcane, or directly burning plant material, for example, sugarcane husks after they have been processed.

Energy sources

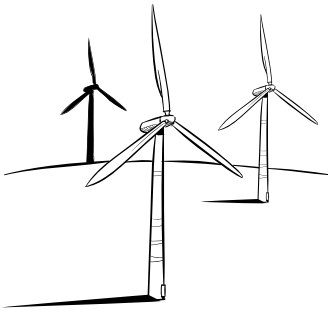
Water



Hydroelectric power stations do not burn fuel. They use water falling from great heights (gravitational energy becoming movement energy) to turn large vanes of water turbines connected to a generator.

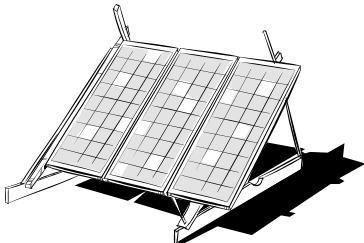
There are also projects investigating how to harness the movement energy of ocean waves.

Wind



Wind turbines use the movement energy of the wind to turn their large turbines connected to a generator.

Sun



Solar panels generate electricity without turbines, by allowing light energy from the Sun to fall on special cells on the panels. These transform the light energy into electrical energy.

Nuclear



The centre of an atom, the nucleus, can be broken in some atoms, and a little of its mass can be turned directly into a lot of energy. The energy released is primarily heat. This can happen naturally or can be induced in nuclear reactors. The heat in the crust of the Earth is partly from nuclear decay and partly from the original formation of the planet. The heat from this process is known as geothermal energy and can be used to heat water and houses, and to drive turbines to generate electrical energy.

Lesson 5 In one direction

AT A GLANCE

To support students to represent and explain their understanding of how electrical energy can be transferred and transformed in electrical circuits and can be generated from a range of sources.

To introduce current scientific views

Students:

- revise their cutaway diagram of how a circuit works in a torch from Lesson 1
- participate in a demonstration of an analogy of an electric circuit
- review their cutaway diagram explaining how a circuit works.

Lesson focus

In the *Explain* phase students develop a literacy product to represent their developing understanding. They discuss and identify patterns and relationships within their observations. Students consider the current views of scientists and deepen their own understanding.

EXPLAIN

Assessment focus



Formative assessment is an ongoing aspect of the *Explore* phase. It involves monitoring students' developing understanding and giving feedback that extends their learning. In this lesson you will monitor students' developing understanding of how:

- electrical energy can be transferred and transformed in electrical circuits and can be generated from a range of sources.

You will also monitor their developing science inquiry skills (see page xi).

You are also able to look for evidence of students' use of appropriate ways to represent what they know and understand about electrical circuits and sources of energy, and give them feedback on how they can improve their representations.

Key lesson outcomes

Science

Students will be able to:

- explain the role of electrons in transferring electrical energy around a circuit
- explain that electrical energy is transformed into other energy types.

Literacy

Students will be able to:

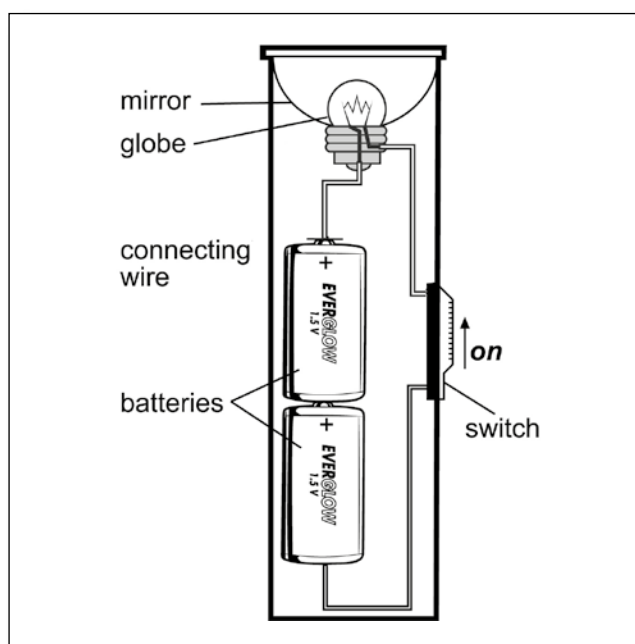
- show understanding of how a circuit works through observation and discussion using an analogy
- represent their understanding through drawing an cutaway diagram of a circuit
- use scientific vocabulary appropriately in writing and talking
- record ideas on a TWLH chart
- participate in and contribute to discussions, clarifying ideas.

This lesson also provides opportunities to monitor the development of students' general capabilities (highlighted through icons, see page xii).

Teacher background information

Torches transform the energy stored in their batteries into light and heat energy at the light globe. The energy is carried from the battery to the light globe by very tiny particles called electrons. These particles are part of all atoms that make up all substances, including the wires in a closed circuit.

The battery in an electric circuit causes the electrons to flow around the wires, and through any devices in the circuit, such as bulbs, motors or buzzers. The electrons flow from the negative terminal toward the positive terminal. The metal wires in an electrical circuit are full of electrons, which start to flow in one direction when the battery is attached, and the switch is closed.



Labelled diagram of the parts of a torch

The battery voltage is a measure of how much push the battery can create. If you place two batteries in a circuit in the same direction, then their voltages will add together. Light bulbs and other devices often have indications of how much voltage they can safely tolerate.

Energy is not produced from nothing, nor is it consumed, nor does it disappear into nothing. In a torch circuit, the chemical energy in the battery is transformed into electrical energy, which is in turn transformed into light and heat energy in the bulb.

The battery's chemical energy is released as electrical energy when the battery is connected into a complete circuit. The electrons already in the circuit components then flow continuously from the negative terminal to the positive terminal when the switch is closed. The chemical reaction in the battery can occur, very slowly, even when a circuit is not connected. This is why batteries have a 'shelf life'.

Equipment

FOR THE CLASS

- class science journal
- TWLH chart
- team roles chart
- team skills chart
- word wall
- 1 enlarged copy of 'Chains of thought' (Resource sheet 6)
- bicycle (see 'Preparation')
- *optional*: digital camera

FOR EACH TEAM

- science journal
- 1 copy of 'Chains of thought' (Resource sheet 6)

EXPLAIN

Preparation

- Ask a student who has a bicycle at school to park it outside the classroom. Explain that it will be used for a demonstration.
- Prepare an enlarged copy of 'Chains of thought' (Resource sheet 6).
- *Optional*: Display 'Chains of thought' (Resource sheet 6) in a digital format.

Lesson steps



- 1 Review the previous lessons using the class science journal and the TWLH chart. Discuss what students have learned about electrical circuits and sources of energy.
- 2 Ask students to work in their collaborative teams and revise their cutaway diagram of how a circuit works in a torch from Lesson 1. Ask students to create a new cutaway diagram to explain how a circuit works in a torch. Ask students to incorporate what they have learned so far in the unit.
- 3 Re-form teams. Allow time for teams to complete the activity.
- 4 Explain that students will discuss an analogy to understand what happens in an electric circuit. Discuss the purpose and features of an analogy.

Literacy focus

Why do we use an analogy?

We use an **analogy** to show how the features of two things are alike in some way.

What does an analogy include?

An **analogy** might be in spoken or written form and might include models, diagrams or role-plays.

- 5 Bring in the bicycle (see 'Preparation') and place it upside down in the middle of the room. Tell students that the bicycle will provide an analogy of how a circuit works because there are similarities between a bicycle and a circuit.
- 6 Turn the pedals of the bicycle and ask students to watch the links of the chain move. Explain that the chain represents the electrons in the circuit, the pedals represent the battery and the small wheel represents the bulb.
- 7 As the bicycle chain is moving, ask the following questions:
 - What types of energy are there? What is transferred? What is transformed?
 - What would happen to the wheel if there were a break in the chain?
 - What would happen if we added friction to the wheel, for example, by lightly holding the brakes? Why does this happen?
 - Is it the links touching the pedals that provide the energy to the wheel directly? How is the energy transferred?
- 8 Discuss how in a circuit the electrons are already in the wires and the components of the circuit (the chain of the bicycle is always present in the analogy). The energy provided by the push of the battery (the legs of the bicyclist on the pedals in the analogy) causes them all to move, which transfers energy to the light (the wheel).
- 9 Introduce the enlarged copy of 'Chains of thought' (Resource sheet 6). Explain that students will reflect on the strengths and weaknesses of the analogy on their copy of the resource sheet.
- 10 Allow time for students to complete their copy of 'Chains of thought' (Resource sheet 6).



PrimaryConnections
Circuits and switches

Chains of thought

Name: _____ Date: _____

1. Draw a line to match the parts of the bicycle chain with the parts of the electric circuit to explain how a circuit works.

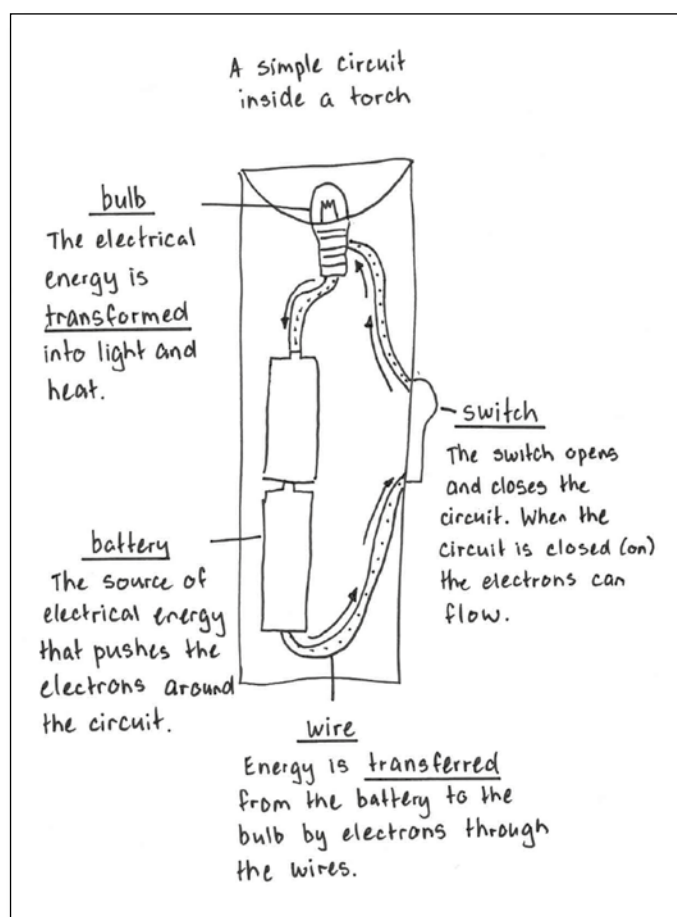
Bicycle chain	Electric circuit
Links in the bicycle chain	The light globe
The pedals	The electrical energy
The small wheel	The push on the electrons by the battery
The moving links	The electrons
The push (from the cyclist) on the links by the pedals	The battery

2. How does this analogy show that electrical energy is not 'used up' by the light globe?

The links in the bicycle chain don't disappear they just keep moving in one direction around the circuit.

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Work sample of 'Chains of thought' (Resource sheet 6)



Sample of a class circuit annotated diagram



- 11** Ask students to share their thoughts. Encourage students to question each other using the 'Science question starters' (see Appendix 7).

Optional: Ask students to try the analogy using the different circuits investigated, such as longer wires, more bulbs, or using a buzzer or a motor.

Optional: Take digital photos of the model of the analogy.

- 12** Discuss how analogies in science can be powerful tools to help conceptual scientific understanding, but that they rarely cover all aspects of a science phenomenon accurately. For example, in a battery-powered circuit, a complete circuit is required for the push to be created (whereas the foot of the bicyclist can push even if there is no chain).
- 13** Explain that students will work in their collaborative learning teams to review their latest cutaway diagram and update it, if necessary, using a different-coloured pen or pencil.



- 14** Re-form teams and allow teams time to complete the activity.
- 15** As a class, record an agreed circuit diagram of a torch with annotations in the class science journal.

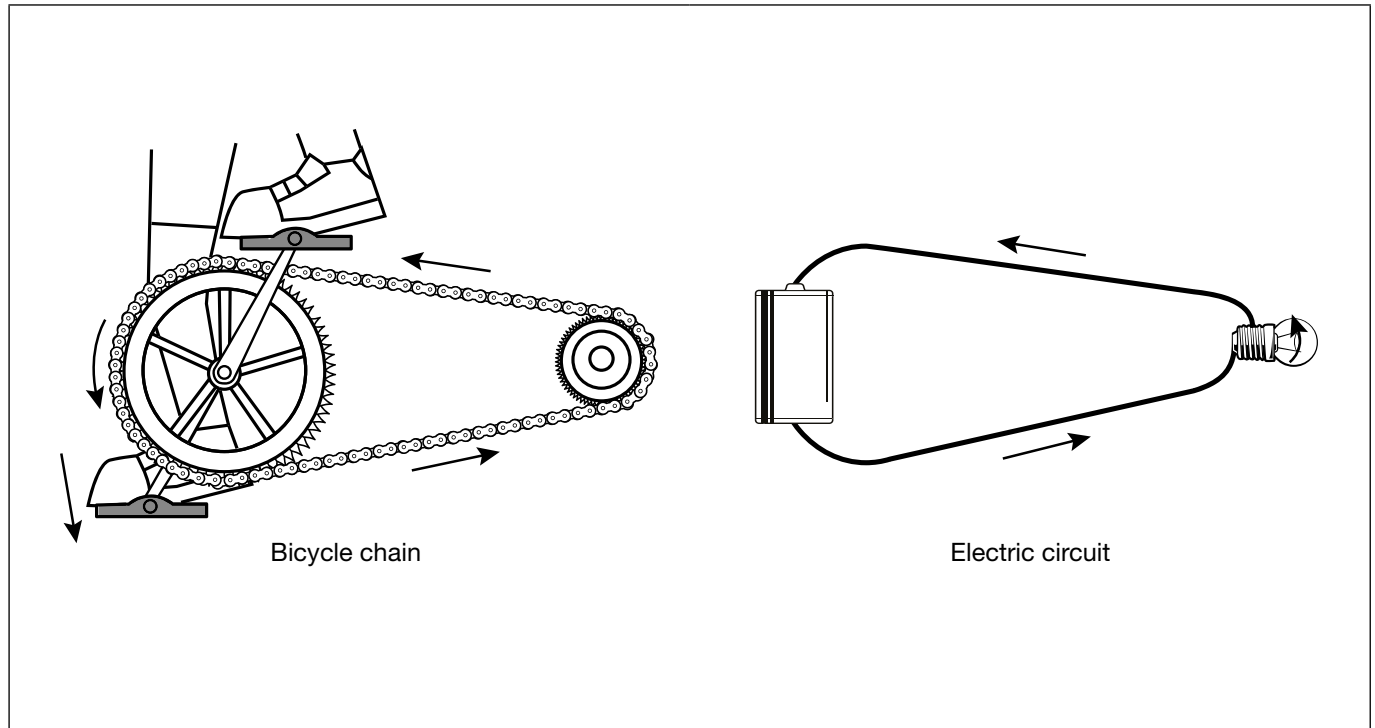
Curriculum links

Science

- Invite an electrician to the class to answer students' questions about electrical circuits.

Chains of thought

Name: _____ Date: _____



1. Draw a line to match the parts of the bicycle chain with the parts of the electric circuit to explain how a circuit works.

Bicycle chain

Links in the bicycle chain
The pedals
The small wheel
The moving links
The push (from the cyclist) on the links by the pedals

Electric circuit

The light globe
The electrical energy
The push on the electrons by the battery
The electrons
The battery

2. How does this analogy show that electrical energy is not 'used up' by the light globe?

Lesson 6 Switch it on!

AT A GLANCE

To support students to plan and conduct an investigation of the function of switches in an electrical circuit.

Students:

- plan and conduct an investigation to make a switch for a simple electrical circuit
- create a circuit diagram including the switch symbol.

Lesson focus

In the *Elaborate* phase students plan and conduct an open investigation to apply and extend their new conceptual understanding in a new context. It is designed to challenge and extend students' science understanding and science inquiry skills.

Assessment focus



Summative assessment of the Science Inquiry Skills is an important focus of the *Elaborate* phase (see page v).

Key lesson outcomes

Science

Students will be able to:

- identify and describe materials that are insulators and conductors
- make a switch for a simple circuit
- explain how switches are used to control the flow of electrical energy around a circuit.

This lesson also provides opportunities to monitor the development of students' general capabilities (highlighted through icons, see page xii).

Literacy

Students will be able to:

- represent their understanding of switches using a circuit diagram
- participate in and contribute to discussions, sharing information, experiences and opinions.

Teacher background information

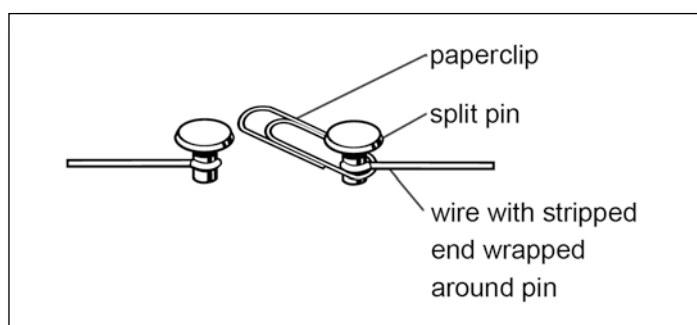
Switches

A switch is a device in an electric circuit that can either provide a path for electrons to flow through or not, depending on whether it is 'closed' or 'open'. For electrons to flow through the circuit and for the battery to convert chemical energy into electrical energy, there needs to be a continuous, conducting path between the negative battery terminal and the positive battery terminal. By placing a switch in a circuit you can control whether the circuit is closed or not. Therefore, you can prevent the battery from converting its chemical energy when it is not needed, without having to remove it each time.

The interior of a switch is made of conductive materials, which allow electrons to flow through them. When the switch is 'on', the circuit is closed (it has no gaps in it and the bulb lights up. When the switch is 'off' or open, it creates an 'open' circuit. With no continuous path for electrons, the battery does not transform chemical energy into electrical energy and the electrons do not move around the circuit.

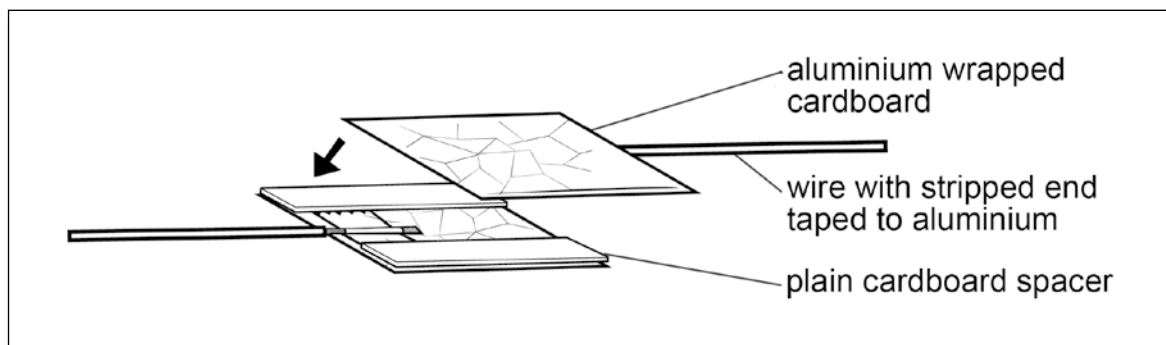
The exterior of a switch is made of insulating materials, which do not conduct electrons easily. The human body can conduct electricity and so the electrons could flow through it as part of the circuit. This is not a safety issue for low voltage direct currents such as provided by a small battery in the classroom. However, switches at home, for example, light switches, operate at much higher voltage, and are constructed to insulate you from the electrical circuits they are completing.

In this lesson students are encouraged to develop their own ideas for how to make a switch. Some common switches in primary classes are:



Example of a paperclip switch

To make a paperclip switch, wrap the ends of wire around split pins. Place a plain wire paperclip around the base of one split pin before anchoring it. When the paperclip touches the second pin the circuit will complete.

The pressure switch:

Cover two cards with aluminium foil. Tape the ends of a wire to each one. Place unwrapped cardboard between the two as a spacer (the cardboard is an insulator). When you press down the aluminium sheets will touch completing the circuit.

Conductors and insulators

All materials are made of atoms. Electrons are small, negatively charged particles that form the outside part of atoms. Some materials contain electrons that held loosely by the atoms and are free to move throughout the material. Materials that have these free electrons are called conductors. Metals have many free electrons, and are considered to be good conductors.

Materials such as glass or plastic have electrons that are not free to move. Therefore, they do not allow electrons to flow through them and are called insulators. Common insulators include plastics, rubber, wood and glass. A plastic insulator is used on electric switches and wires to prevent shock or electrical injury to a person using them.

The human body is a conductive material and people can be harmed if they become part of an electrical circuit with a voltage higher than about 40V. The danger depends on the amount of electrical energy (voltage in the circuit). Electrical energy above a certain threshold will cause muscle contraction, meaning if a person touches a wire with the palm of their open hand, the hand snaps shut, and they cannot detach themselves from the current. Length of contact, amount of electrical energy and factors like sweat on skin determine the severity of symptoms, from burns to interfering with the functioning of the heart and the nervous system.

Equipment

FOR THE CLASS

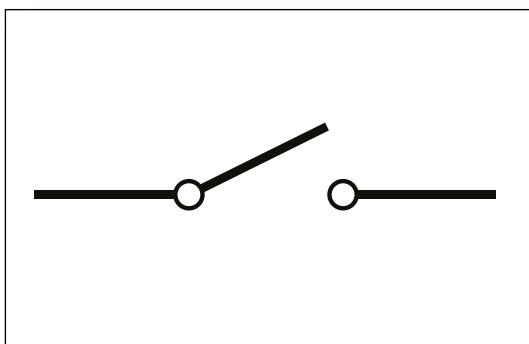
- class science journal
- team roles chart
- team skills chart
- TWLH chart
- word wall
- 1 enlarged copy of 'Making switches' (Resource sheet 7)

FOR EACH TEAM

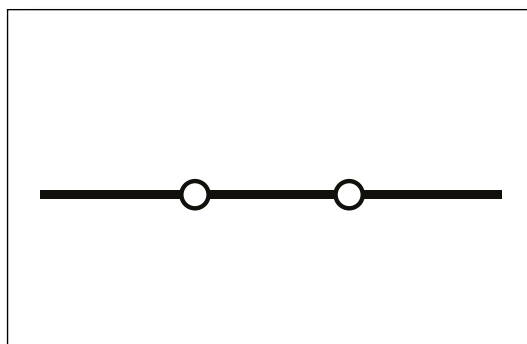
- each team member's science journal
- role wristbands or badges for Director, Manager and Speaker
- 1 copy of 'Making switches' (Resource sheet 7) per team member
- 1 battery (1.5V)
- 1 light bulb (1.5V) or LED
- 1 electric buzzer (3V)
- 1 electric motor (1.5V)
- 3 x 10 cm lengths of insulated wire, with ends stripped of insulation
- self-adhesive tape
- wooden items (eg, toothpicks, corks)
- plastic items (eg, straws)
- rubber items (eg, rubber bands, balloons)
- metal items (eg, paperclips, thumb tacks,铝箔, split pins)
- *optional*: Ohmmeter

Preparation

- Prepare an enlarged copy of 'Making switches' (Resource sheet 7).
- Add the following symbols to the 'Standard electrical symbols' page in the class science journal:



Symbol for switch in 'off' position



Symbol for switch in 'on' position

- *Optional*: Display 'Making switches' (Resource sheet 7) in a digital format.

Lesson steps

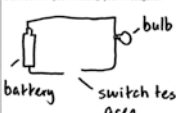
- 1 Review the previous lesson, focusing on the circuit diagrams made in Lesson 5.
- 2 Discuss how the switch on the torch examined in Lesson 1 is used to turn the torch on and off. Brainstorm examples of other types of switches that students have used and how they might work. Record students' responses in the class science journal.
- 3 Explain that students will be working in teams to design a switch for their battery-operated model that they will plan and make in the next lesson.
- 4 Discuss how they will need to choose appropriate materials for the different parts of the switch.
- 5 Ask students how they might test different materials that might be used to make a switch. Remind students how placing two bulbs in series meant that the electrical energy was shared between them. Discuss what students would expect to see if a material with no resistance, for example, a wire, were placed in series with a light bulb, and what would happen if a material with a lot of resistance, for example, a block of wood, were placed in series with a light bulb. Record students' thoughts in the class science journal.
- 6 Introduce the enlarged copy of 'Making switches' (Resource sheet 7). Read through and discuss how to complete each section with students.

PrimaryConnections
Circuits and switches

Making switches

Name: _____ Date: _____

Other members of your team: _____

<p>What are you going to investigate?</p> <p>What will happen to the bulb in a circuit when we change the materials we use for a switch?</p>	<p>What do you predict will happen? Why?</p> <p>I predict that things made out of metal will work best as switches because they let the electrical energy through.</p>	
<p>Can you write it as a question?</p> <p>To make this a fair test what things (variables) are you going to:</p>		
<p>Change?</p> <p>The material that the switch is made from.</p>	<p>Observe?</p> <p>Whether the bulb lights up or not.</p>	<p>Keep the same?</p> <p>The rest of the circuit.</p>
<p>Change only one thing</p>	<p>What would the change affect?</p>	<p>Which variables will you control?</p>
<p>Describe how you will set up your investigation</p> 		<p>What equipment will you need?</p> <p>Circuit - battery, bulb and wires</p> <p>Materials - paperclips, aluminium foil, nails, toothpicks, pen lid.</p>
<p>Write and draw your observations in your science journal</p>		

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Work sample of page 1 of 'Making switches' (Resource sheet 7)

- 7 Introduce the equipment table and the materials students will use to conduct their investigation and make a switch. Explain that the teams can choose to use an electric buzzer or electric motor instead of the bulb to test the conductivity of materials
Optional: Students directly test the resistance of materials using an Ohmmeter.
- 8 Form teams and allocate roles. Ask Managers to collect team equipment.
Allow time for teams to conduct their investigation of materials and design their switches.
- 9 Ask Speakers to present their team's results and designs. Encourage students to ask questions of the team using the 'Science question starters' (see Appendix 7).

PrimaryConnections
Circuits and switches

Recording results
Record your results in a table.

Materials tested	Result
paperclips	✓
toothpick	x
nail	✓
alfoil	✓
pen lid	x
drawing pin	✓
paper	x
my finger	x
sharpener	x

Explaining results
Write a statement to summarise your findings about the materials investigated.

All the objects that were made out of metal let the electrical energy pass through and light up the bulb.

Evaluating the investigation

What challenges did you have doing this investigation?	How could you improve this investigation? (fairness, accuracy)
Keep the circuit closed by keeping the wires touching the battery and bulb	To keep it fair I would use a battery holder and bulb holder.

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Work sample of page 2 of 'Making switches' (Resource sheet 7)



10 Ask questions such as:

- Which material did you use to make your switch with?
Why did you choose that material?
- What other material could you have also used? How do you know that?
- What part does the switch play in the circuit? (When it is not connected, it stops the flow of the electrical energy. When it is connected, the electrical energy can flow.)
- Why do we use a switch in a circuit? (To have more control over when the electrical energy is flowing; so that energy is not wasted; so that the battery does not go flat.)

11 Ask students if they know what term scientists use to describe materials that allow electrical energy to pass through them (conductors) and what term is used for materials that do not allow electrical energy to pass through them (insulators). Add these terms to the class glossary.

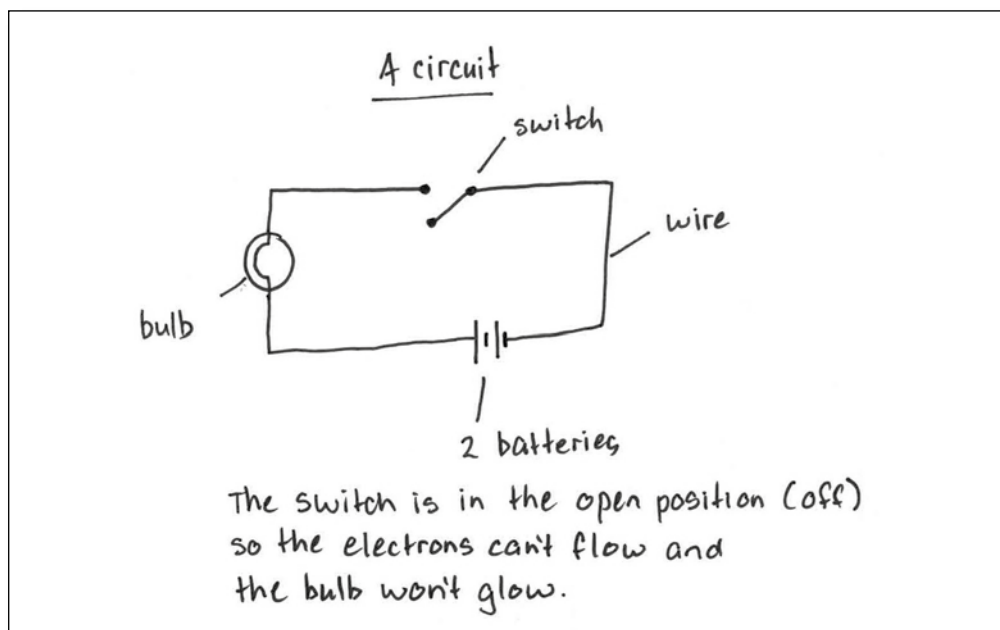


12 Ask students if they have noticed patterns among materials that are good conductors and among those that are good insulators. Many metals, such as copper, iron and steel, are good electrical conductors. Plastic, wood, glass and rubber are good electrical insulators.

13 Compare switches constructed by the teams with the brainstorm about switch types in lesson step 2. If no teams created a pressure switch, discuss how one might work.

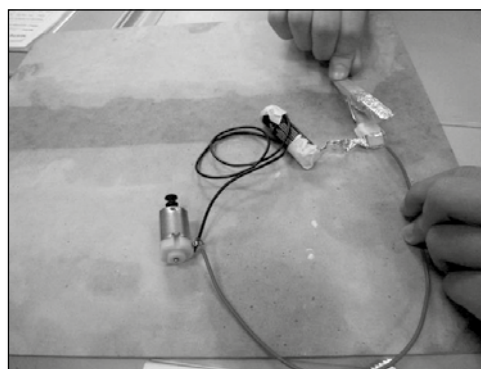
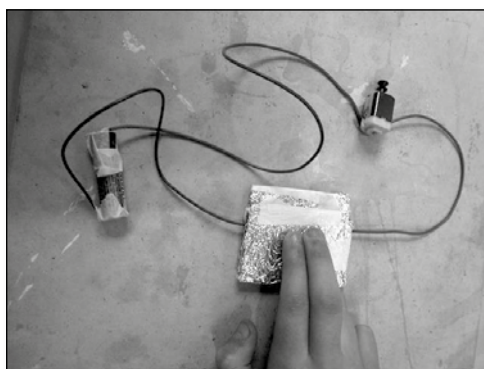
14 Introduce the electric symbol for an open and a closed switch in the class science journal (see 'Preparation'). Ask students which position represents a switch that allows a circuit to function and why they think that.

15 Ask students to draw a circuit diagram in their science journals that includes a switch, using electrical symbols. Ask them to annotate the diagram to describe the role of the switch in a circuit.



Student work sample of an annotated circuit diagram including a switch

- 16** Update the TWLH chart and word wall with words and images.



Work samples of two different types of switches

Making switches

Name: _____ Date: _____

Other members of your team: _____

What are you going to investigate?

What do you predict will happen? Why?

Can you write it as a question?

Give scientific explanations for your prediction

To make this a fair test what things (variables) are you going to:

Change?

Observe?

Keep the same?

Change only one thing

What would the change affect?

Which variables will you control?

Describe how you will set up your investigation

What equipment will you need?

Use drawings if necessary

Use dot points

Write and draw your observations in your science journal

Recording results

Record your results in a table.

Materials tested	Result

Explaining results

Write a statement to summarise your findings about the materials investigated.

Evaluating the investigation

What challenges did you have doing this investigation?

How could you improve this investigation?
(fairness, accuracy)

Lesson 7 Making models

AT A GLANCE

To support students to design, make and appraise a model that uses a circuit to transform energy from one form to another.

Session 1 Plan it

Students:

- plan and develop a procedure to make a model that uses a circuit to work.

Session 2 Make it

Students:

- follow their procedure to construct a model that meets agreed criteria.

Lesson focus

In the *Elaborate* phase students plan and conduct an open investigation to apply and extend their new conceptual understanding in a new context. It is designed to challenge and extend students' science understanding and science inquiry skills.

Assessment focus



Summative assessment of the Science Inquiry Skills is an important focus of the *Elaborate* phase (see page v).

Key lesson outcomes

Science

Students will be able to:

- generate and develop ideas to make a model that includes an electric circuit
- make an electric circuit that safely transfers and transforms electrical energy in a model
- identify how the components of the circuit transfer and transform energy.

Literacy

Students will be able to:

- record ideas as an ideas map
- create an annotated drawing of their ideas
- develop a procedure of how to make the device
- participate in and contribute to discussions, sharing information, experiences and opinions.

This lesson also provides opportunities to monitor the development of students' general capabilities (highlighted through icons, see page xii).

Session 1 Plan it

Equipment

FOR THE CLASS

- class science journal
- team roles chart
- team skills chart
- TWLH chart
- word wall
- 1 enlarged copy of 'Circuit model planner' (Resource sheet 8)


FOR EACH TEAM

- each team member's science journal
- role wristbands or badges for Director, Manager and Speaker
- 1 copy of 'Circuit model planner' (Resource sheet 8) per team member

Preparation

- Prepare an enlarged copy of 'Circuit model planner' (Resource sheet 8).
- *Optional:* Display 'Circuit model planner' (Resource sheet 8) in a digital format.

Lesson steps

- 1 Review previous lessons using the class science journal, TWLH chart and word wall.
- 2 Discuss an electrical circuit, each of its components and how electrical energy is transferred and transformed in the circuit.
- 3 Explain that students will work in collaborative learning teams to design, produce and evaluate a model that contains an electrical circuit and transforms electrical energy to another type of energy, such as sound, light or motion energy. Examples of models might include a lighthouse, a doll's house or traffic light.
- 4 Explain that teams will present the model to the rest of the class and explain what is happening in terms of circuits and transforming energy.
- 5 Explain that teams need to consider and include safety in the planning and production of their design. Discuss examples of possible safety issues, for example, the use of trimmers.
- 6  Discuss how the class will decide if each team has completed the task successfully. For example, the class might decide that the model will:
 - Use a working electrical circuit including a switch.
 - Transform electrical energy from a battery to another form of energy.
 - Use classroom materials.
 - Be sturdy (won't fall apart when being touched).
 - Be well presented (nice to look at).

Explain that this is called the 'criteria' that each team's model will be assessed on.



- 7 As a class, use an ideas map to record students' ideas about the types of models that they might produce. Discuss the purpose and features of an ideas map.

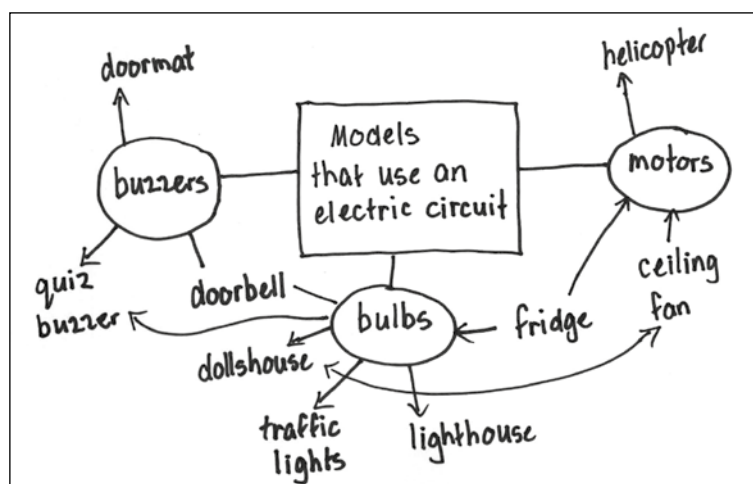
Literacy focus

Why do we use an ideas map?

We use an **ideas map** to show our thoughts about a topic.

What does an ideas map include?

An **ideas map** includes a title in the centre. Ideas are written around it and arrows are drawn between similar ideas. An **ideas map** might include pictures and symbols.



Work sample of an ideas map

- 8 Ask teams to discuss each of the ideas before selecting one, and then draw an annotated diagram of what the model will look like. Discuss the purpose and features of an annotated diagram.

Literacy focus

Why do we use an annotated diagram?

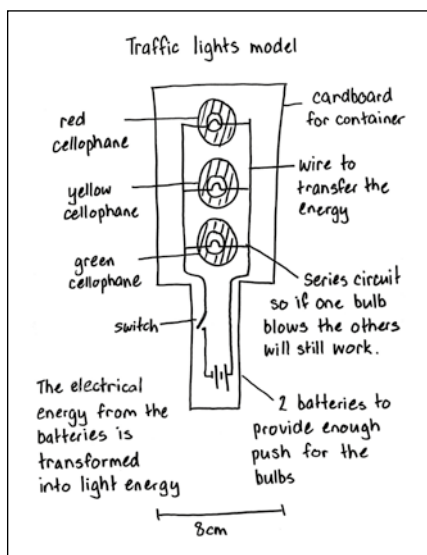
We use an **annotated diagram** to show the parts of an object and what they do.

What does an annotated diagram include?

An **annotated diagram** might include an accurate drawing, a title, a date and a few words about each of the parts. A line or arrow joins the words to the part.



- 9 Form teams and allocate roles. Allow time for teams to complete the activity.



Work sample of an annotated diagram

- 10 Introduce an enlarged copy of 'Circuit model planner' (Resource sheet 8). Read through and discuss.
- 11 Explain that teams will plan the equipment and procedure for making their model. Discuss the purpose and features of a procedural text.

Literacy focus

Why do we use a procedural text?

We use a **procedural text** to describe how something is done. We can read a **procedural text** to find out how to do things

What does a procedural text include?

A **procedural text** includes a list of materials needed to do the task and a description of the sequence of steps used. It might include annotated diagrams.



- 12 Re-form teams. Allow time for teams to complete the activity.
- 13 Update the TWLH chart and word wall with words and images.

ELABORATE

Circuit model planner	
Name: _____ Date: _____	
Other members of your team: _____	
Aim: To produce a model that contains an electric circuit and transforms electrical energy into another type of energy.	
Procedure: _____	
Equipment	Reason for selecting this equipment
• Cardboard	to make the shape of the traffic light
• 2 batteries	to provide the electrical energy
• 3 globes	for the lights
• Wire	to transfer the energy
• cellophane	to colour the lights
• paperclips	for the switch
<div> <div>Production steps</div> <ol style="list-style-type: none"> 1. Make the circuit using the bulbs, batteries and wire 2. Place circuit in light shaped box 3. Cover holes with cellophane 4. Include switch </div> <div> <div>Labelled diagram of model</div> </div>	

Work sample of 'Circuit model planner' (Resource sheet 8)

Circuit model planner

Name: _____ **Date:** _____

Other members of your team: _____

Aim:

Procedure:

Equipment	Reason for selecting this equipment

Production steps	Labelled diagram of model

Session 2 Make it Equipment

FOR THE CLASS

- class science journal
- team roles chart
- team skills chart
- TWLH chart
- word wall
- materials to make models (see 'Preparation')

FOR EACH TEAM

- each team member's science journal
- role wristbands or badges for Director, Manager and Speaker

Preparation

- Prepare materials for teams to make models based on their completed 'Circuit model planner' (Resource sheet 8) from Session 1.

Lesson steps

- 1 Revise the previous session, focusing on the planned models the teams will make that uses a circuit to transform electrical energy. Ask teams to briefly explain what they are planning to make.
- 2 Explain that in this session the teams will follow their production steps and equipment list to make their model.
- 3 Show students the equipment table with the equipment that the teams had listed on their 'Circuit model planner' (Resource sheet 8).
- 4 Re-form teams and ask Managers to collect team equipment. Allow time for teams to complete the activity.



Lesson 8 Present it!

AT A GLANCE

To provide opportunities for students to represent what they know about how electrical energy can be transferred and transformed in electrical circuits and can be generated from a range of sources, and to reflect on their learning during the unit.

Students:

- prepare a description that communicates the main ideas of their model and how an electric circuit works
- share models and descriptions with the class
- reflect on their learning during the unit.

Lesson focus

In the *Evaluate* phase students reflect on their learning journey and create a literacy product to re-represent their conceptual understanding.

Assessment focus



Summative assessment of the Science Understanding descriptions is an important aspect of the *Evaluate* phase. In this lesson you will be looking for evidence of the extent to which students understand how:

- electrical energy can be transferred and transformed in electrical circuits and can be generated from a range of sources.

Key lesson outcomes

Science

Students will be able to:

- describe a circuit in terms of components that form a continuous path for the flow of electrons
- describe how energy is transferred within an electric circuit
- explain different sources of energy.

Literacy

Students will be able to:

- present a model that uses an electric circuit
- make a presentation to communicate their understanding of electrical circuits
- reflect on their learning in the unit.

This lesson also provides opportunities to monitor the development of students' general capabilities (highlighted through icons, see page xii).

Equipment

FOR THE CLASS

- class science journal
- team roles chart
- team skills chart
- TWLH chart
- word wall
- *optional*: digital camera

FOR EACH STUDENT

- each team member's science journal
- role wristbands or badges for Director, Manager and Speaker

Preparation

- Prepare a page in the class science journal with the criteria decided on in the previous lesson by the class. For example:

Circuits and switches models

Criteria	Team 1	Team 2	Team 3	Team 4	Team 5	Team 6	Team 7
Uses a working electrical circuit including a switch							
Transforms electrical energy from a battery to another form of energy							
Uses classroom materials							
Is sturdy							
Is well presented							

Lesson steps



- 1 Explain that teams will present their models, which will be reviewed by the rest of the class who will provide feedback.
- 2 Discuss the information that you will be looking for to assess students' models and descriptions. Ask students to provide the following information about their model in their science journals:
 - Describe the electric circuit in your model.
 - What are the components of the electric circuit? What role does each component have in the circuit?
 - What happens to the energy in the circuit? Use the words 'transferred' and 'transformed'.
 - What happens if the circuit breaks?
 - Where is the source of energy coming from in your circuit? What other sources can generate electrical energy?



- 3 Re-form teams. Allow time for teams to prepare their presentations.



- 4 Ask teams to make their presentations of their models to the class.

Optional: Review oral presentation skills, such as looking at the audience and using appropriate voice, volume and pace.

Optional: Take photos of presented models.

- 5 Introduce the prepared table in the class science journal (see 'Preparation'). Explain that the class will discuss each team presentation and provide feedback on each criterion.
- 6 Use the class science journal and TWLH chart to review the unit and how students' ideas have changed and developed during the unit.
- 7 Ask questions such as:
 - What activities did you enjoy? Why?
 - What activities didn't you enjoy? Why not?
 - How have your ideas changed? Which ideas have stayed the same?
 - What are you still wondering about?



'Door buzzer'



'Fridge'



'Helicopter'



'Lighthouse'

Work samples of student models

Appendix 1

How to organise collaborative learning teams (Year 3–Year 6)

Introduction

Students working in collaborative teams is a key feature of the PrimaryConnections inquiry-based program. By working in collaborative teams students are able to:

- communicate and compare their ideas with one another
- build on one another's ideas
- discuss and debate these ideas
- revise and rethink their reasoning
- present their final team understanding through multimodal representations.

Opportunities for working in collaborative learning teams are highlighted throughout the unit.

Students need to be taught how to work collaboratively. They need to work together regularly to develop effective group learning skills.

The development of these collaborative skills aligns to descriptions in the Australian Curriculum: English. See page xiii.

Team structure

The first step towards teaching students to work collaboratively is to organise the team composition, roles and skills. Use the following ideas when planning collaborative learning with your class:

- Assign students to teams rather than allowing them to choose partners.
- Vary the composition of each team. Give students opportunities to work with others who might be of a different ability level, gender or cultural background.
- Keep teams together for two or more lessons so that students have enough time to experience working together successfully.
- If you cannot divide the students in your class into teams of three, form two teams of two students rather than one team of four. It is difficult for students to work together effectively in larger groups.
- Keep a record of the students who have worked together as a team so that by the end of the year each student has worked with as many others as possible.

Team roles

Students are assigned roles within their team (see below). Each team member has a specific role but all members share leadership responsibilities. Each member is accountable for the performance of the team and should be able to explain how the team obtained its results. Students must therefore be concerned with the performance of all team members. It is important to rotate team jobs each time a team works together so that all students have an opportunity to perform different roles.

For Year 3–Year 6, teams consist of three students: Director, Manager and Speaker. (For F–Year 2, teams consist of two students: Manager and Speaker.) Each member of the team should wear something that identifies them as belonging to that role, such as a wristband, badge, or colour-coded peg. This makes it easier for you to identify which role each student is doing and it is easier for the students to remember what they and their team mates should be doing.

Manager

The Manager is responsible for collecting and returning the team's equipment. The Manager also tells the teacher if any equipment is damaged or broken. All team members are responsible for clearing up after an activity and getting the equipment ready to return to the equipment table.

Speaker

The Speaker is responsible for asking the teacher or another team's Speaker for help. If the team cannot resolve a question or decide how to follow a procedure, the Speaker is the only person who may leave the team and seek help. The Speaker shares any information they obtain with team members. The teacher may speak to all team members, not just to the Speaker. The Speaker is not the only person who reports to the class; each team member should be able to report on the team's results.

Director (Year 3–Year 6)

The Director is responsible for making sure that the team understands the team investigation and helps team members focus on each step. The Director is also responsible for offering encouragement and support. When the team has finished, the Director helps team members check that they have accomplished the investigation successfully. The Director provides guidance but is not the team leader.

Team skills

PrimaryConnections focuses on social skills that will help students work in collaborative teams and communicate more effectively.

Students will practise the following team skills throughout the year:

- Move into your teams quickly and quietly
- Speak softly
- Stay with your team
- Take turns
- Perform your role.

To help reinforce these skills, display enlarged copies of the team skills chart (see the end of this Appendix) in a prominent place in the classroom.

Supporting equity

In science lessons, there can be a tendency for boys to manipulate materials and girls to record results. Primary **Connections** tries to avoid traditional social stereotyping by encouraging all students, irrespective of their gender, to maximise their learning potential. Collaborative learning encourages each student to participate in all aspects of team activities, including handling the equipment and taking intellectual risks.

Observe students when they are working in their collaborative teams and ensure that both girls and boys are participating in the hands-on activities.

TEAM ROLES

Manager

Collects and returns all materials the team needs

Speaker

Asks the teacher and other team speakers for help

Director

Makes sure that the team understands the team investigation and completes each step

TEAM SKILLS

- 1** Move into your teams quickly and quietly
- 2** Speak softly
- 3** Stay with your team
- 4** Take turns
- 5** Perform your role

Appendix 2

How to use a science journal

Introduction

A science journal is a record of observations, experiences and reflections. It contains a series of dated, chronological entries. It can include written text, drawings, measurements, labelled diagrams, photographs, tables and graphs.

Using a science journal provides an opportunity for students to be engaged in a real science situation as they keep a record of their observations, ideas and thoughts about science activities. Students can use their science journals as a useful self-assessment tool as they reflect on their learning and how their ideas have changed and developed during a unit.

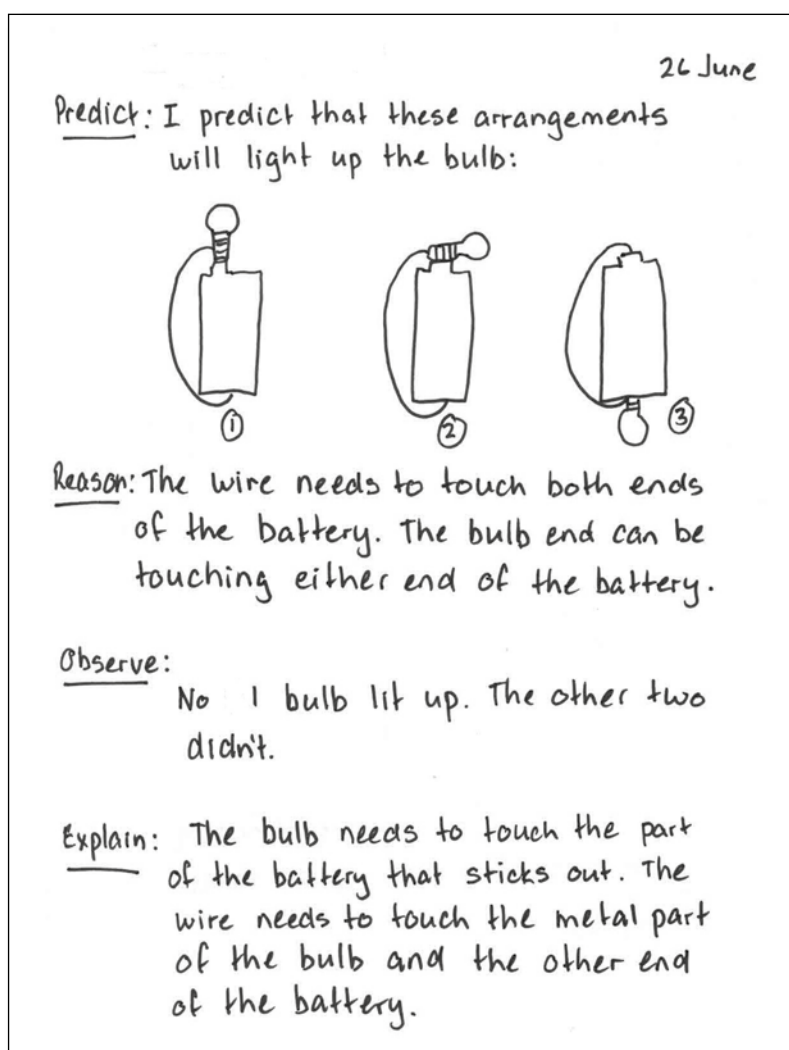
Monitoring students' journals allows you to identify students' alternative conceptions, find evidence of students' learning and plan future learning activities in science and literacy.

Keeping a science journal aligns to descriptions in the Australian Curriculum: Science and English. See pages xi and xiii.

Using a science journal

- 1** At the start of the year, or before starting a science unit, provide each student with a notebook or exercise book for their science journal or use an electronic format. Tailor the type of journal to fit the needs of your classroom. Explain to students that they will use their journals to keep a record of their observations, ideas and thoughts about science activities. Emphasise the importance of including pictorial representations as well as written entries.
- 2** Use a large project book or A3 paper to make a class science journal. This can be used at all year levels to model journal entries. With younger students, the class science journal can be used more frequently than individual journals and can take the place of individual journals.
- 3** Make time to use the science journal. Provide opportunities for students to plan procedures and record predictions, and their reasons for predictions, before an activity. Use the journal to record observations during an activity and reflect afterwards, including comparing ideas and findings with initial predictions and reasons. It is important to encourage students to provide evidence that supports their ideas, reasons and reflections.
- 4** Provide guidelines in the form of questions and headings and facilitate discussion about recording strategies, such as note-making, lists, tables and concept maps. Use the class science journal to show students how they can modify and improve their recording strategies.
- 5** Science journal entries can include narrative, poetry and prose as students represent their ideas in a range of styles and forms.
- 6** In science journal work, you can refer students to display charts, pictures, diagrams, word walls and phrases about the topic displayed around the classroom. Revisit and revise this material during the unit. Explore the vocabulary, visual texts and ideas that have developed from the science unit, and encourage students to use them in their science journals.

- 7 Combine the use of resource sheets with journal entries. After students have pasted their completed resource sheets in their journal, they might like to add their own drawings and reflections
- 8 Use the science journal to assess student learning in both science and literacy. For example, during the *Engage* phase, use journal entries for diagnostic assessment as you determine students' prior knowledge.
- 9 Discuss the importance of entries in the science journal during the *Explain* and *Evaluate* phases. Demonstrate how the information in the journal will help students develop literacy products, such as posters, brochures, letters and oral or written presentations.



Circuits and switches science journal entry

Appendix 3

How to use a word wall

Introduction

A word wall is an organised collection of words and images displayed in the classroom. It supports the development of vocabulary related to a particular topic and provides a reference for students. The content of the word wall can be words that students see, hear and use in their reading, writing, speaking, listening and viewing.

Creating a class word wall, including words from different dialects and languages, aligns to descriptions in the Australian Curriculum: English. See page xiii.

Goals in using a word wall

A word wall can be used to:

- support science and literacy experiences of reading, viewing, writing and speaking
- provide support for students during literacy activities across all key learning areas
- promote independence in students as they develop their literacy skills
- provide a visual representation to help students see patterns in words and decode them
- develop a growing bank of words that students can spell, read and/or use in writing tasks
- provide ongoing support for the various levels of academic ability in the class
- teach the strategy of using word sources as a real-life strategy.

Organisation

Position the word wall so that students have easy access to the words. They need to be able to see, remove and return word cards to the wall. A classroom could have one main word wall and two or three smaller ones, each with a different focus, for example, high-frequency words.

Choose robust material for the word cards. Write or type words on cardboard and perhaps laminate them. Consider covering the wall with felt-type material and backing each word card with a self-adhesive dot to make it easy for students to remove and replace word cards.

Word walls do not need to be confined to a wall. Use a portable wall, display screen, shower curtain or window curtain. Consider a cardboard shape that fits with the unit, for example, an apple for a needs unit.

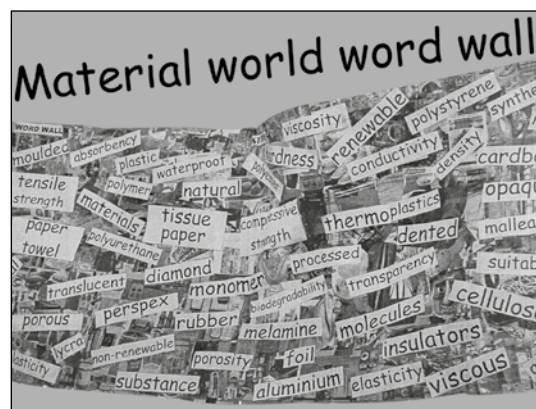
The purpose is for students to be exposed to a print-rich environment that supports their science and literacy experiences.

Organise the words on the wall in a variety of ways. Place them alphabetically, or put them in word groups or groups suggested by the unit topic, for example, words for a circuits unit might be organised under headings, such as 'Energy types' and 'Energy sources'.

Invite students to contribute words from different languages to the word wall. Group words about the same thing, for example, different names of the same piece of clothing on the word wall so that students can make the connections. Identify the different languages used, for example, by using different-coloured cards or pens to record the words.



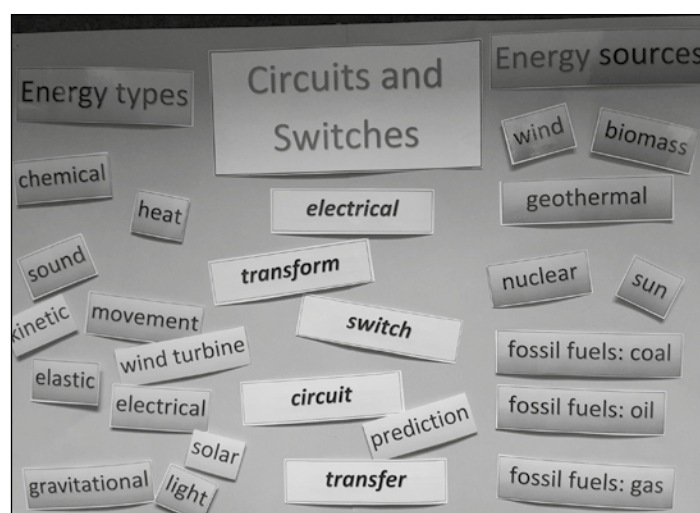
Desert survivors word wall



Material world word wall

Using a word wall

- 1 Limit the number of words to those needed to support the science and literacy experiences in the classroom.
- 2 Add words gradually, and include images where possible, such as drawings, diagrams or photographs. Build up the number of words on the word wall as students are introduced to the scientific vocabulary of the unit
- 3 Encourage students to interact with the word wall. Practise using the words with students by reading them and playing word games. Refer to the words during science and literacy experiences and direct students to the wall when they need a word for writing. Encourage students to use the word wall to spell words correctly.
- 4 Use the word wall with the whole class, small groups and individual students during literacy experiences. Organise multi-level activities to cater for the individual needs of students.



Circuits and switches word wall

Appendix 4

How to use a glossary

Introduction

A glossary is a list of technical terms that relate to a particular subject matter or topic, generally accompanying a document. Each term is accompanied by a description or explanation of the term within the context of the subject. A glossary entry is generally more descriptive than a dictionary definition

Creating a class glossary can be used to:

- elicit students' prior understanding of subject-specific term
- develop a growing bank of descriptions to help students understand and use new words in written and oral tasks
- support students' understanding of scientific descriptions and explanations
- develop the strategy of using word sources as a real-life, valuable investigative research strategy.

Using a class glossary

- 1 Introduce a term and discuss what it might mean within the context of the unit. Possible strategies include students connecting the word to a feature or aspect of the topic, and students using the word in a spoken sentence to explain topic, concept or context.
 - 2 Create a shared understanding of the term, and record it in the science journal or as part of the word wall.
 - 3 Introduce the conventional technical meaning of the term where appropriate.
 - 4 Encourage students to practise using the terms in the glossary to become familiar with them. Students may wish to amend a description of a word after becoming more familiar with how it is used in a particular context. This may occur when writing, talking or making annotations to diagrams.
 - 5 Integrate the glossary across all curriculum areas where appropriate. For example, in a literacy lesson discuss various meanings for the term.
 - 6 The glossary could be a part of the science journal or the word wall for a particular unit.
- Note:** It is important to ask students for 'descriptions' of the terms rather than 'definitions' 'Definitions' are often viewed as fixed and unchangeable, whereas 'descriptions' support students to see that ideas can change as their understanding develops.

Appendix 5

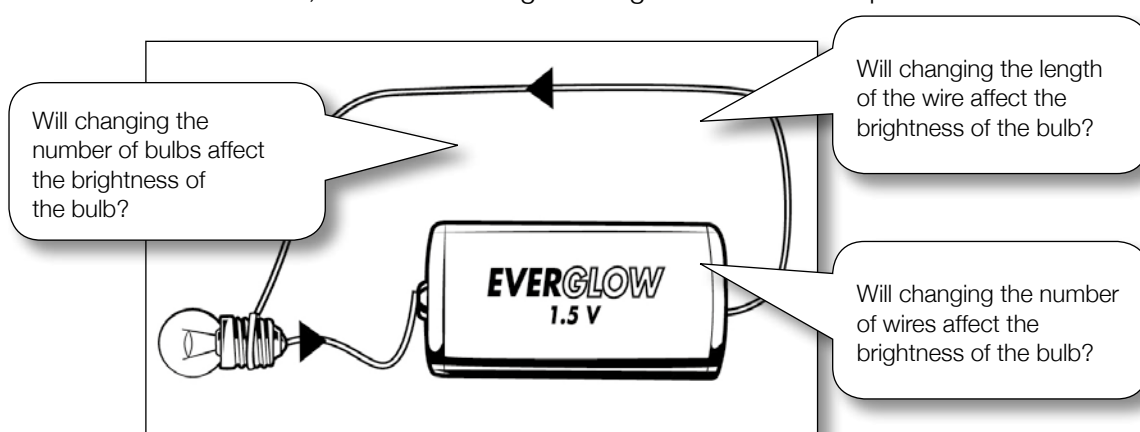
How to conduct a fair test

Introduction

Scientific investigations involve posing questions, testing predictions, planning and conducting tests, interpreting and representing evidence, drawing conclusions and communicating findings

Planning a fair test

In *Circuits and switches*, students investigate things that affect a simple electrical circuit.



All scientific investigations involve *variables*. Variables are things that can be changed (independent), measured/observed (dependent) or kept the same (controlled) in an investigation. When planning an investigation, to make it a fair test, we need to identify the variables.

It is only by conducting a fair test that students can be sure that what they have changed in their investigation has affected what is being measured/observed.

'Cows **Moo Softly**' is a useful scaffold to remind students how to plan a fair test:

Cows: **Change** one thing (independent variable)

Moo: **Measure/Observe** another thing (dependent variable)

Softly: keep the other things (controlled variables) the **Same**.

To investigate whether the number of batteries has an effect on the brightness of a bulb, students could:

CHANGE	The number of bulbs	Independent variable
MEASURE/ OBSERVE	The brightness of the bulb	Dependent variable
KEEP THE SAME	The type of bulb, the length of wire, the number of wires, the voltage of batteries	Controlled variables

Introduction

Primary**Connections** has developed an adaptation called the **TWLH** chart.

W—‘What we **want** to learn’ encourages students to list questions for investigation. Further questions can be added as students develop their understanding.

H—‘How we know’ or ‘How we came to our conclusion’ is used in conjunction with the third column and encourages students to record the evidence and reasoning that lead to their new claim, which is a key characteristic of science. This last question requires students to reflect on their investigations and learning, and to justify their claims.

As students reflect on their observations and understandings to complete the third and fourth columns, ideas recorded in the first column should be reconsidered and possibly confirmed, amended or discarded, depending on the investigation findings

Circuits and switches TWLH chart

What we think we know	What we want to learn	What we learned (What are our claims)	How we know (What is our evidence)
<p>We think the number of bulbs in a circuit will make the bulbs shine brighter.</p> <p style="text-align: right;">→</p>	<p>Do too many bulbs make the bulbs brighter or dimmer?</p> <p style="text-align: right;">→</p>	<p>The more bulbs that you add the dimmer the bulbs glow.</p> <p style="text-align: right;">→</p>	<p>One bulb shone brightly, two bulbs made the bulb a bit dimmer, three bulbs made the bulb even dimmer.</p>

Appendix 7

How to facilitate evidence-based discussions

Introduction

Argumentation is at the heart of what scientists do; they pose questions, make claims, collect evidence, debate with other scientists and compare their ideas with others in the field

In the primary science classroom, argumentation is about students:

- articulating and communicating their thinking and understanding to others
- sharing information and insights
- presenting their ideas and evidence
- receiving feedback (and giving feedback to others)
- finding flaws in their own and others' reasoning
- reflecting on how their ideas have changed

It is through articulating, communicating and debating their ideas and arguments that students are able to develop a deep understanding of science content.

Establish norms

Introduce norms before starting a science discussion activity. For example:

- Listen when others speak.
- Ask questions of each other.
- Criticise ideas not people.
- Listen to and discuss all ideas before selecting one.

Claim, Evidence and Reasoning

In science, arguments that make claims are supported by evidence. Sophisticated arguments follow the **QCER** process:

Q – What **question** are you trying to answer? For example, 'Does the number of bulbs in a circuit affect their brightness?'

C – The **claim**. For example, 'The more bulbs in a circuit the duller the bulbs become'.

E – The **evidence**. For example, 'When I increased the number of bulbs in a circuit the bulbs became duller each time another bulb was added'.

R – The **reasoning**. For example, 'The more bulbs there are the harder it is for the electrical energy to flow. There is more resistance in the circuit.'

Students need to be encouraged to move from making claims only, to citing evidence to support their claims. Older students develop full conclusions that include a claim, evidence and reasoning. This is an important characteristic of the nature of science and an aspect of scientific literacy. Using science question starters (see next section) helps to promote evidence-based discussion in the classroom.

Science question starters

Science question starters can be used to model the way to discuss a claim and evidence for students. Teachers encourage team members to ask these questions of each other when preparing their claim and evidence. They might also be used by audience members when a team is presenting its results. (See PrimaryConnections 5Es video, Elaborate).

Science question starters

Question type	Question starter
Asking for evidence	I have a question about _____. What is your evidence to support your claim?
Agreeing	I agree with _____ because _____.
Disagreeing	I disagree with _____ because _____. One difference between my idea and yours is _____.
Questioning further	I wonder what would happen if _____? I have a question about _____. I wonder why _____? What caused _____? How would it be different if _____?
Clarifying	I'm not sure what you meant there. Could you explain your thinking to me again?

DISCUSSION SKILLS

- Listen when others speak
- Ask questions of each other
- Criticise ideas not people
- Listen to and discuss all ideas before selecting one

Appendix 8

How to write questions for investigation

Introduction

Scientific inquiry and investigation are focused on and driven by questions. Some questions are open to scientific investigation, while others are not. Students often experience difficulty in developing their own questions for investigation.

This appendix explains the structure of questions and how they are related to variables in a scientific investigation. It describes an approach to developing questions for investigation and provides a guide for constructing investigable questions with your students.

Developing their own questions for investigation helps students to have ownership of their investigation and is an important component of scientific literacy.

The structure of questions for investigation

The way that a question is posed in a scientific investigation affects the type of investigation that is carried out and the way information is collected. Examples of different types of questions for investigation include:

- How does/do ...?
- What effect does ...?
- Which type of ...?
- What happens to ...?

All science investigations involve variables. Variables are things that can be changed (independent), measured (dependent) or kept the same (controlled) in an investigation.

- The **independent variable** is the thing that is changed during the investigation.
- The **dependent variable** is the thing that is affected by the independent variable, and is measured or observed.
- **Controlled variables** are all the other things in an investigation that could change but are kept the same to make it a fair test.

An example of the way students can structure questions for investigation is:

What happens to _____ when we change _____?

dependent variable

independent variable

The type of question for investigation in *Circuits and switches* refers to two things (variables) and the relationship between them, for example, an investigation of the things (variables) that affect the brightness of a bulb might consider the number of bulbs and the length of the wires. The question for investigation could be:

Q1: What happens to the brightness of a bulb when we change the number of bulbs?

In this question, *the brightness of a bulb* depends on *the number of bulbs*. *The number of bulbs* is the thing that is **changed** (independent variable) and the brightness of the bulb is the thing that is **measured or observed** (dependent variable).

Q2: What happens to the brightness of a bulb when we change the number of wires?

In this question, *the brightness of a bulb* depends on *the number of wires*. *The number of wires* is the thing that is **changed** (independent variable) and the brightness of a bulb is the thing that is **measured or observed** (dependent variable).

An example of the way students can structure questions for investigation in *Circuits and switches* is:

What happens to _____ when we change _____?

dependent variable **independent variable**

Developing questions for investigation

The process of developing questions for investigation is to:

- Provide a context and reason for investigating.
- Pose a general focus question in the form of:

'What things might affect _____ **dependent variable**)?'.

For example, ‘What things might affect an electrical circuit?’

- Use questioning to elicit the things (**independent variables**) students think might affect the dependent variable, for example, the brightness of a bulb.

By using questions, elicit the things that students can investigate, such as the number of batteries, the length of the wires, the number of wires. These are the things that could be changed (**independent variables**), which students predict will affect the thing that is measured or observed (**dependent variable**).

- Each of the independent variables can be developed into a question for investigation.
- Use the scaffold 'What happens to _____ when we change _____?' to help students develop specific questions for their investigation.

For example, ‘What happens to the brightness of a bulb when we change the number of bulbs?’ or ‘What happens to the brightness of a bulb when we change the number of wires?’.

- Ask students to review their question for investigation after they have conducted their investigation and collected and analysed their information.
- Encouraging students to review their question will help them to understand the relationship between what was changed and what was measured in their investigation. It also helps students to see how the information they collected relates to their prediction.

Appendix 9 Circuits and switches equipment list

EQUIPMENT ITEM	QUANTITIES	LESSON		1		2		3		4		5		6		7		8	
		SESSION		1	2	1	2	1	2	1	2	1	2	1	2	1	2	1	2
Equipment and materials																			
battery (1.5V)	1 per team																		
battery (1.5V)	1 per team																		
battery (1.5V)	3 per team																		
bicycle	1 per class																		
buzzer, electric (3V)	1 per class																		
buzzer, electric (3V)	1 per team																		
collection of different-sized batteries	per team																		
elastic bands	2 per team																		
light bulb (1.5V) or LED	1 per team																		
light bulb (1.5V)	3 per team																		
light bulb holder and battery holder	1 per team																		
materials to make models	per class																		
metal items (eg, paperclips, thumb tacks,铝箔, split pins)	per team																		
mobile phone	1 per class																		
motor, electric (1.5V)	1 per class																		
motor, electric (1.5V)	1 per team																		
Ohmmeter <i>optional</i>	1 per team																		
plastic items (eg, straws)	per team																		
rubber items (eg, rubber bands, balloons)	per team																		
spare light bulbs, batteries and wire	per class																		
stripping pliers or knife	1 per class																		
tape, self-adhesive	per team																		
torch, battery-operated	1 per class																		
torch, inside components (eg, wires, bulb, batteries)	per class																		
torches, old <i>optional</i>	per class																		
wire, 10 cm length, with ends stripped of insulation	2 per team																		
wire, 10 cm length, with ends stripped of insulation	3 per team																		
wire, 10 cm length, with ends stripped of insulation	6 per team																		
wooden items (eg, toothpicks, corks)	per team																		

EQUIPMENT ITEM	QUANTITIES	LESSON		1	2	2	3	4	4	4	5	6	7	7	8
		SESSION			1	2		1	2				1	2	
Resource sheets															
'Light it up!' (RS1)	1 per team member			•	•	•									
'Light it up!' (RS1), enlarged	1 per class			•	•	•									
'Perplexing circuits' (RS2)	1 per team member						•								
'Perplexing circuits' (RS2), enlarged	1 per class						•								
'Appliances survey' (RS3)	1 per team member							•							
'Appliances survey' (RS3), enlarged	1 per class							•							
'Alessandro Volta: Battery maker' (RS4)	1 per student									•					
'Alessandro Volta: Battery maker' (RS4), enlarged	1 per class									•					
'Energy sources' (RS5)	1 per student														
'Energy sources' (RS5), enlarged	1 per class														
'Chains of thought' (RS6)	1 per student										•				
'Chains of thought' (RS6), enlarged	1 per class										•				
'Making switches' (RS7)	1 per team member											•			
'Making switches' (RS7), enlarged	1 per class											•			
'Circuit model planner' (RS8)	1 per team member												•		
'Circuit model planner' (RS8), enlarged	1 per class												•		
Teaching tools															
class science journal	1 per class			•	•	•	•	•	•	•	•	•	•	•	•
role wristbands or badges for Director, Manager and Speaker	1 set per team				•	•	•	•	•	•	•	•	•	•	•
student science journal	1 per student			•	•	•	•	•	•	•	•	•	•	•	•
team roles chart	1 per class				•	•	•	•	•	•	•	•	•	•	•
team skills chart	1 per class				•	•	•	•	•	•	•	•	•	•	•
TWLH chart	1 per class			•	•	•	•	•	•	•	•	•	•	•	•
word wall	1 per class			•	•	•	•	•	•	•	•	•	•	•	•
Multimedia															
digital camera <i>optional</i>											•				•

Appendix 10

Circuits and switches unit overview

		SCIENCE OUTCOMES*	LITERACY OUTCOMES*	LESSON SUMMARY	ASSESSMENT OPPORTUNITIES
ENGAGE	Lesson 1 What makes it work?	<ul style="list-style-type: none"> Students will be able to represent their current understanding as they: explain their existing ideas of how a torch works explain what they know about electrical circuits identify sources of energy. 	<p>Students will be able to:</p> <ul style="list-style-type: none"> use a cutaway diagram to display information record ideas on a TWLH chart participate in and contribute to discussions, sharing information, experiences and opinions. 	<p>Students:</p> <ul style="list-style-type: none"> create a cutaway diagram of how they think a torch works discuss what they know about electrical circuits and sources of energy. 	Diagnostic assessment <ul style="list-style-type: none"> Science journal entries Class discussions TWLH chart Cutaway diagrams
	Lesson 2 Get it to glow	<ul style="list-style-type: none"> make predictions about circuits that will light a light bulb construct and test circuits and record their observations compare their representations of circuits. 	<ul style="list-style-type: none"> use writing, drawing and modelling to record predictions, observations and explanations about circuits represent a circuit diagram using symbols record ideas on a TWLH chart participate in and contribute to discussions, sharing information, experiences and opinions. 	<p>Session 1 Light it up!</p> <ul style="list-style-type: none"> construct and test different arrangements of a circuit. <p>Session 2 Standard symbols</p> <ul style="list-style-type: none"> use symbols to draw a circuit diagram. 	Formative assessment <ul style="list-style-type: none"> Science journal entries Class discussions TWLH chart 'Light it up!' (Resource sheet 1) Circuit diagrams

*For information on how the lessons align with the relevant descriptions of the Australian Curriculum, see page xi for Science and page xiii for English and Mathematics.

	SCIENCE OUTCOMES*		LITERACY OUTCOMES*	LESSON SUMMARY		ASSESSMENT OPPORTUNITIES
	Students will be able to:		Students will be able to:	Students:		
EXPLORE	Lesson 3 Circuit scenarios	<ul style="list-style-type: none">plan and conduct a fair test investigationrecord and analyse dataprovide evidence and reasoning to support claims.	<ul style="list-style-type: none">complete a PROE on investigationsrecord ideas on a TWLH chartparticipate in and contribute to discussions, sharing information, experiences and opinions.	<ul style="list-style-type: none">identify questions that can be investigated on the effects of changing different components of a circuitplan, conduct and evaluate a fair test investigation.		Formative assessment <ul style="list-style-type: none">Science journal entriesClass discussionsTWLH chart‘Perplexing circuits’ (Resource sheet 2)
	Lesson 4 Make it go	<ul style="list-style-type: none">identify different energy transformations in a circuitidentify different sources of energyunderstand that scientific explanations are revised as new evidence emerges.	<ul style="list-style-type: none">read and summarise a biographyread a factual textuse a survey to collect informationrecord ideas on a TWLH chartparticipate in and contribute to discussions, sharing information, experiences and opinions.	Session 1 Energy sources <ul style="list-style-type: none">survey devices for energy sources and transformations. Session 2 The battery maker <ul style="list-style-type: none">read and discuss a biography of Alessandro Voltaread a factual text on how electrical energy is made.		Formative assessment <ul style="list-style-type: none">Science journal entriesClass discussionsTWLH chart‘Appliances survey’ (Resource sheet 3)

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EXPLAIN	SCIENCE OUTCOMES*	LITERACY OUTCOMES*	LESSON SUMMARY	ASSESSMENT OPPORTUNITIES
	Students will be able to:	Students will be able to:	Students:	
Lesson 5 In one direction	<ul style="list-style-type: none">explain the role of electrons in transferring electrical energy around a circuitexplain that electrical energy is transformed into other energy types.	<ul style="list-style-type: none">show understanding of how a circuit works through observation and discussion using an analogyrepresent their understanding through drawing an cutaway diagram of a circuituse scientific vocabulary appropriately in writing and talkingrecord ideas on a TWLH chartparticipate in and contribute to discussions, clarifying ideas.	<ul style="list-style-type: none">revise their cutaway diagram of how a circuit works in a torch from Lesson 1participate in a demonstration of an analogy of an electric circuitreview their cutaway diagram explaining how a circuit works.	Formative assessment <ul style="list-style-type: none">Science journal entriesClass discussionsTWLH chart‘Chains of thought’ (Resource sheet 6)Cutaway diagrams

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	SCIENCE OUTCOMES*		LITERACY OUTCOMES*	LESSON SUMMARY	ASSESSMENT OPPORTUNITIES
	Students will be able to:		Students will be able to:	Students:	
ELABORATE	Lesson 6 Switch it on!	<ul style="list-style-type: none">• identify and describe materials that are insulators and conductors• make a switch for a simple circuit• explain how switches are used to control the flow of electrical energy around a circuit.	<ul style="list-style-type: none">• represent their understanding of switches using a circuit diagram• participate in and contribute to discussions, sharing information, experiences and opinions.	<ul style="list-style-type: none">• plan and conduct an investigation to make a switch for a simple electric circuit• create a circuit diagram including the switch symbol.	Summative assessment of Science Inquiry Skills <ul style="list-style-type: none">• Science journal entries• Class discussions• 'Making switches' (Resource sheet 7)
ELABORATE	Lesson 7 Making models	<ul style="list-style-type: none">• generate and develop ideas to make a model that includes an electric circuit• make an electric circuit that safely transfers and transforms electrical energy in a model.• identify how the components of the circuit transfer and transform energy.	<ul style="list-style-type: none">• record ideas as an ideas map• create an annotated drawing of their ideas• develop a procedure of how to make the device• participate in and contribute to discussions, sharing information, experiences and opinions.	Session 1 Plan it <ul style="list-style-type: none">• plan and develop a procedure to make a model that uses a circuit to work. Session 2 Make it <ul style="list-style-type: none">• follow their procedure to construct a model that meets agreed criteria.	Summative assessment of Science Inquiry Skills <ul style="list-style-type: none">• Science journal entries• Class discussions• 'Circuit model planner' (Resource sheet 8)• Annotated diagram• Ideas map

*For information on how the lessons align with the relevant descriptions of the Australian Curriculum, see page xi for Science and page xiii for English and Mathematics.

	SCIENCE OUTCOMES*	LITERACY OUTCOMES*	LESSON SUMMARY	ASSESSMENT OPPORTUNITIES
	Students will be able to:	Students will be able to:	Students:	
EVALUATE Lesson 8 Present it!	<ul style="list-style-type: none"> describe a circuit in terms of components that form a continuous path for the flow of electrons describe how energy is transferred within an electric circuit explain different sources of energy. 	<ul style="list-style-type: none"> present a model that uses an electric circuit make a presentation to communicate their understanding of electrical circuits reflect on their learning in the unit. 	<ul style="list-style-type: none"> prepare a description that communicates the main ideas of their model and how an electric circuit works share models and descriptions with the class reflect on their learning during the unit. 	Summative assessment Science Understanding <ul style="list-style-type: none"> Science journal entries Class discussions Models

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PrimaryConnections Units

Year	Biological sciences	Chemical sciences	Earth and space sciences	Physical sciences
F	Staying alive	That's my hat!	Weather in my world	On the move
	Growing well	What's it made of?		
1	Schoolyard safari	Spot the difference	Changes all around	Look! Listen!
	Dinosaurs and more	Bend it! Stretch it!	Up, down and all around	
2	Watch it grow!	All mixed up	Water works	Machine makers
				Push-pull
3	Feathers, fur or leaves?	Melting moments	Night and day	Heating up
4	Plants in action	Material world	Beneath our feet	Magnetic moves
	Friends or foes?	Package it better		Smooth moves
	Among the gum trees			
5	Desert survivors	What's the matter?	Earth's place in space	Light shows
6	Marvellous micro-organisms	Change detectives	Creators and destroyers	Circuits and switches
	Rising salt		Earthquake explorers	Essential energy