PrimaryConnections®
Linking science with literacy

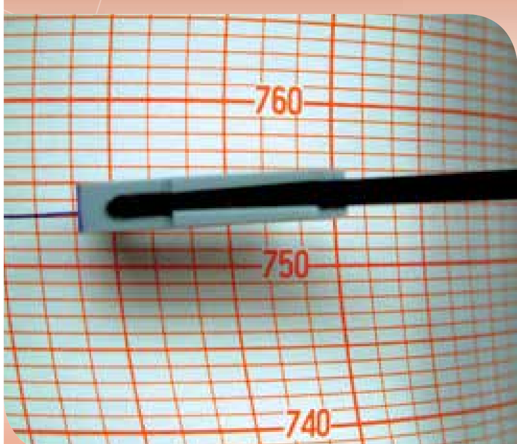
Fully aligned with the Australian Curriculum

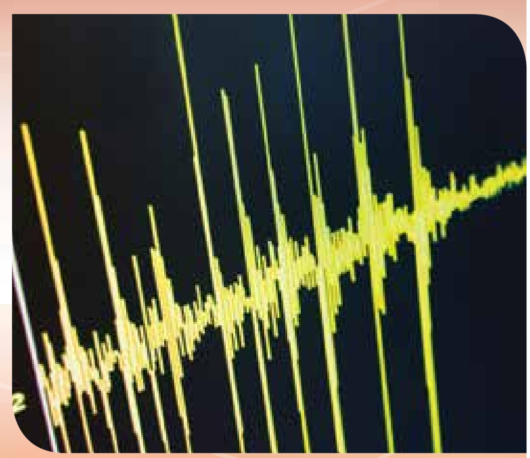
The PrimaryConnections program is supported by astronomer, Professor Brian Schmidt, 2011 Nobel Laureate

Earthquake explorers

Year 6

Earth and space sciences



Primary**Connections** project

Director Ms Shelley Peers (Australian Academy of Science)

Reference Group
Professor Jenny Graves, AO FAA (Australian Academy of Science) [Chair]
Ms Shelley Peers (Australian Academy of Science)
ACT Department of Education and Training
Australian Council of Deans of Education
Australian Curriculum Assessment and Reporting Authority (ACARA)
Australian Government Department of Education, Employment and Workplace Relations
Australian Literacy Educators' Association
Australian Primary Principals Association
Australian Science Teachers Association
QLD Department of Education, Training and Employment
Independent Schools Council of Australia
Indigenous Education Consultative Body
National Catholic Education Commission
NSW Department of Education and Communities
NT Department of Education and Training
Primary English Teaching Association Australia
SA Department for Education and Child Development
TAS Department of Education
VIC Department of Education and Early Childhood Development
WA Department of Education

Australian Government

Australian Academy of Science

Professional learning program

The Primary**Connections** program includes a sophisticated professional learning component and exemplary curriculum resources. Research shows that this combination is more effective than using each in isolation.

Professional Learning Facilitators are available throughout Australia to conduct workshops on the underpinning principles of the program: the Primary**Connections** 5Es teaching and learning model, linking science with literacy, investigating, embedded assessment and collaborative learning.

The Primary**Connections** website has contact details for state and territory Professional Learning Coordinators, as well as additional resources for this unit. Visit the website at:
www.science.org.au/primaryconnections

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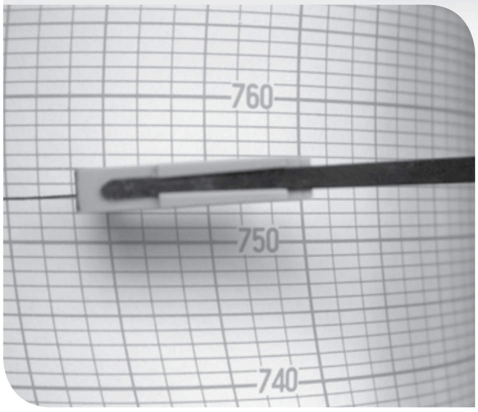

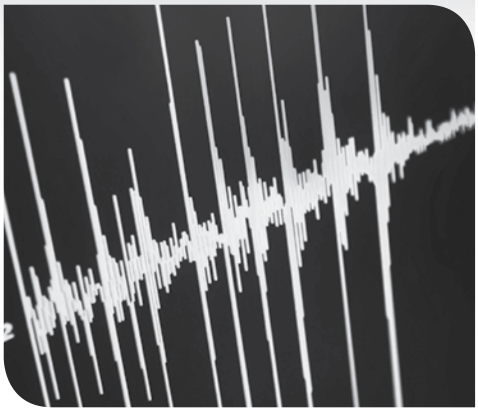

Major earthquakes cause dramatic changes to the Earth's surface. Strong earthquakes can affect millions of lives by causing buildings to collapse, destroying roadways and bridges and affecting basic necessities such as electricity and water supply. Fortunately, the majority of earthquakes are barely noticed. It is still not possible to accurately predict where and when an earthquake will happen. However, greater understanding of their causes helps scientists estimate the locations and likelihood of future damaging earthquakes.

The *Earthquake explorers* unit is an ideal way to link science with literacy in the classroom. Students develop an understanding of the causes of earthquakes and how they change the Earth's surface. Through investigations, students explore earthquake magnitude data from Australia and neighbouring countries, drawing conclusions about patterns in the data.

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Contents

Foreword

The Australian Academy of Science is proud of its long tradition of supporting and informing science education in Australia. 'Primary**Connections**: linking science with literacy' is its flagship primary school science program, and it is making a real difference to the teaching and learning of science in Australian schools.

The Primary**Connections** approach has been embraced by schools since its inception in 2004, and there is substantial evidence of its effectiveness in helping teachers transform their practice. It builds teacher confidence and competence in this important area, and helps teachers use their professional skills to incorporate elements of the approach into other areas of the curriculum. Beginning and pre-service teachers find the approach doable and sustainable. Primary**Connections** students enjoy science more than in comparison classes, and Indigenous students, in particular, show significant increases in learning using the approach.

The project has several components: professional learning, curriculum resources, research and evaluation, and Indigenous perspectives. With the development of an Australian curriculum in the sciences by ACARA in December 2010, it is an exciting time for schools to engage with science, and to raise the profile of primary science education.

Students are naturally curious. Primary**Connections** provides an inquiry-based approach that helps students develop deep learning, and guides them to find scientific ways to answer their questions. The lessons include key science background information, and further science information is included on the Primary**Connections** website (www.science.org.au/primaryconnections/science-background-resource/).

Science education provides a foundation for a scientifically literate society which is so important for engagement in key community debates such as climate change, carbon emissions, and immunisation, as well as for personal decisions about health and well-being. The inquiry approach in Primary**Connections** prepares students well to participate in evidence-based discussions of these and other issues.

Primary**Connections** has been developed with the financial support of the Australian Government and has been endorsed by education authorities across the country. The Steering Committee, comprised of Department of Education, Employment and Workplace Relations and Academy representatives, and the Reference Group, which includes representatives from all stakeholder bodies including states and territories, have provided invaluable guidance and support. Before publication, the science teacher background information on science is reviewed by a Fellow of the Academy of Science. All these inputs have ensured an award-winning, quality program.

The Fellows of the Academy are committed to ongoing support for teachers of science at all levels. I commend Primary**Connections** to you and wish you well in your teaching.

Professor Suzanne Cory, AC PresAA FRS
President
Australian Academy of Science
2010–2013

The PrimaryConnections program

PrimaryConnections is an innovative program that links the teaching of science and literacy in the primary years of schooling. It is an exciting and rewarding approach for teachers and students with a professional learning program and supporting curriculum resources. Further information about professional learning and other curriculum support can be found on the PrimaryConnections website. www.science.org.au/primaryconnections

The PrimaryConnections teaching and learning model

This unit is one of a series designed to exemplify the PrimaryConnections teaching and learning approach which embeds inquiry-based learning into a modified 5Es instructional model (Bybee, 1997), with the five phases: *Engage, Explore, Explain, Elaborate* and *Evaluate*. The relationship between the 5Es phases, investigations, literacy products and assessment are 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 explanations	**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.science.org.au/primaryconnections/teaching-and-learning/

Developing students' scientific literacy

The learning outcomes in PrimaryConnections contribute to 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. (Programme for International Student Assessment & Organisation for Economic Co-operation and Development [PISA & OECD], 2009).

Linking science with literacy

Primary**Connections** 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.

Primary**Connections** develops the literacies of science that students need to learn and to represent their understanding of science concepts, processes and skills. Representations in Primary**Connections** are multi-modal 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

Assessment against the year level Achievement standards of the Australian Curriculum: Science (ACARA, 2012) is ongoing and embedded in Primary**Connections** units. Assessment is linked to the development of literacy practices and products. Relevant understandings and skills for each lesson 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 of the Science Inquiry Skills and of the Science Understanding in the *Evaluate* phase.

Alignment with the Australian Curriculum: Science

The Australian Curriculum: Science (ACARA, 2012) 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.'

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
Use and influence of science	How science knowledge and applications affect people's lives 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 regarding 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

AC All the material in this table is sourced from the Australian Curriculum.

There will be a minimum of four Primary**Connections** units for each year of primary school from Foundation to Year 6—at least one for each Science Understanding sub-strand of the Australian Curriculum. Each unit contains detailed information about its alignment with all aspects of the Australian Curriculum: Science and its links to the Australian Curriculum: English and Mathematics.

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 ⚠ SAFETY 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.

References

Australian Curriculum Assessment and Reporting Authority (ACARA). (2012). *Australian Curriculum: Science*. www.australiancurriculum.edu.au

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

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.

Unit at a glance

Earthquake explorers

Phase	Lesson	At a glance
ENGAGE	**Lesson 1** Earthquake explorers	To capture students' interest and find out what they think they know about how sudden geological changes or extreme weather conditions can affect Earth's surface To elicit students' questions about the causes and effects of earthquakes
EXPLORE	**Lesson 2** Energetic earthquakes	To provide students with shared experiences of how the effects, magnitude and intensity of earthquakes are measured
	Lesson 3 Unearthing quakes ***Session 1*** Modelling earthquakes ***Session 2*** Interior insights (*Optional*)	To provide students with hands-on, shared experiences of modelling the changes to the Earth's surface which cause earthquakes
EXPLAIN	**Lesson 4** Explaining earthquakes ***Session 1*** Plates on the move ***Session 2*** Changes over time	To support students to represent and explain their understanding and observations of changes to the Earth's surface which cause earthquakes To introduce students to current scientific views about earthquakes and tectonic plates
ELABORATE	**Lesson 5** Earthquakes down under	To support students to investigate and compare earthquake activity in Australia and neighbouring countries
	Lesson 6 So you want to be a seismologist?	To support students to investigate and model how scientists collect information about earthquakes
EVALUATE	**Lesson 7** On location	To provide opportunities for students to represent what they know about how sudden geological changes or extreme weather conditions can affect Earth's surface, and to reflect on their learning during the unit

A unit overview can be found in Appendix 7, page 84.

Alignment with the Australian Curriculum: Science

This *Earthquake explorers* unit embeds all three strands of the Australian Curriculum: Science. The table below lists sub-strands and their content for Year 6. This unit is designed to be taught in conjunction with other Year 6 units to cover the full range of the Australian Curriculum: Science content for Year 6.

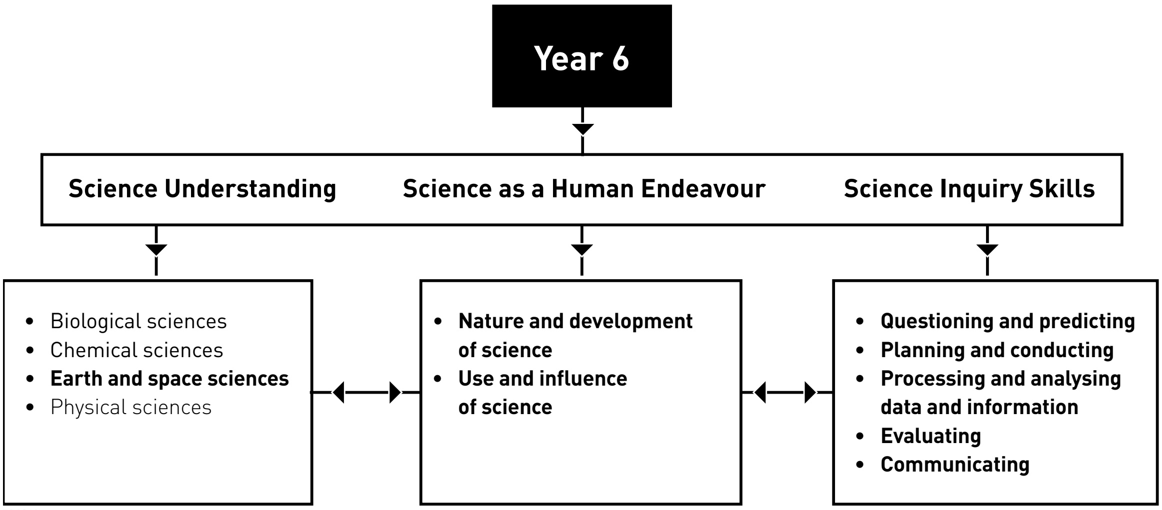
For ease of assessment the table below outlines the sub-strands and their aligned lessons.

Strand	Sub-strand	Code	Year 6 content descriptions	Lessons
Science Understanding	**Earth and space sciences**	ACSSU096	Sudden geological changes or extreme weather conditions can affect Earth's surface	1–7
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	2,3,4,5,7
		ACSHE099	Important contributions to the advancement of science have been made by people from a range of cultures	5
	Use and influence of science	ACSHE100	Scientific understandings, discoveries and inventions are used to solve problems that directly affect peoples' lives	1,2,5,7
		ACSHE220	Scientific knowledge is used to inform personal and community decisions	5,7
Science Inquiry Skills	**Questioning and predicting**	ACSIS232	With guidance, pose questions to clarify practical problems or inform a scientific investigation, and predict what the findings of an investigation might be	3,5
	Planning and conducting	ACSIS103	With guidance, plan appropriate investigation methods to answer questions or solve problems	3,6
		ACSIS104	Decide which variable should be changed and measured in fair tests and accurately observe, measure and record data, using digital technologies as appropriate	3,6
		ACSIS105	Use equipment and materials safely, identifying potential risks	3,6
	Processing and analysing data and information	ACSIS107	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	2,4,5
		ACSIS221	Compare data with predictions and use as evidence in developing explanations	5
	Evaluating	ACSIS108	Suggest improvements to the methods used to investigate a question or solve a problem	6
	Communicating	ACSIS110	Communicate ideas, explanations and processes in a variety of ways, including multi-modal texts	1–7

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

Interrelationship of the Science strands

The interrelationship between the three strands—Science Understanding, Science as a Human Endeavour and Science Inquiry Skills—and their sub-strands is shown below. Sub-strands covered in this unit are in bold.



All the terms in this diagram are sourced from the Australian Curriculum.

Relationship to Overarching ideas

In the Australian Curriculum: Science, six overarching ideas support the coherence and developmental sequence of science knowledge within and across year levels. In *Earthquake explorers*, these overarching ideas are represented by:

Overarching idea	Incorporation in *Earthquake explorers*
Patterns, order and organisation	Students interpret secondary data and organise it in order to recognise patterns in the distribution of earthquakes in the world. They relate these patterns to data on tectonic plates to infer relationships between tectonic plate movement and earthquake activity.
Form and function	Through modelling, students investigate the relationship between the form of the earth's crust and the function of tectonic plates in causing earthquakes and their effects on the Earth's surface.
Stability and change	Students identify that gradual change on a global scale during periods of seeming stability can cause sudden, dramatic changes in a localised area. Students identify that earthquakes are not predictable, but that areas which are more likely to experience earthquakes can be predicted.
Scale and measurement	Students investigate the measurement of earthquake magnitude according to the modified Mercalli and Richter scales and explore how to use a seismometer to measure earthquake activity. They explore how changes to the Earth's surface can be measured by the effect on humans as well as by mathematical models. Students explore processes that occur over geological time and different timescales. They relate these slow processes to events that happen on timescales of days.
Matter and energy	Students explore how the movement energy of the Earth's tectonic plates can cause changes at the Earth's surface; the friction between plates sliding past each other can cause earthquakes and the collision of plates can raise mountains.
Systems	Students relate localised earthquake events to the global system of tectonic plates. They identify some common interactions between the plates, investigating the forces at work and the inputs and outputs of the system.

Curriculum focus

The Australian Curriculum: Science, is described by year level, but provides advice across four year groupings on the nature of learners. Each year grouping has a relevant curriculum focus.

Curriculum focus Years 6	Incorporation in *Earthquake explorers*
Recognising questions that can be investigated scientifically and investigating them	Students create and test models and analyse secondary data about earthquakes to form evidence-based claims about the processes that cause changes to the Earth's surface. Through modelling they explore methods of investigating natural phenomena that cannot be manipulated directly.

Achievement standards

The achievement standards of the Australian Curriculum: Science, indicates the quality of learning that students typically demonstrate by a particular point in their schooling, for example at the end of a year level. These standards will be reviewed regularly by ACARA and are available from the ACARA website.

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 Australian Curriculum: Science Year 6 achievement standard. Rubrics to help teachers make these judgments will be available on the website:
www.science.org.au/primaryconnections/curriculum-resources

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/Generalcapabilities

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

Earthquake explorers—Australian Curriculum General capabilities

General capabilities	Australian Curriculum description	*Earthquake explorers* examples
Literacy	Literacy knowledge specific to the study of science develops along with scientific understanding and skills. Primary**Connections** 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 Earthquake explorers the literacy focuses are: • science journals • storyboards • oral presentations • TWLH charts • glossaries • word walls • factual recounts • cutaway diagrams (optional) • factual texts • timelines • graphs.
Numeracy	Elements of numeracy are particularly evident in Science Inquiry Skills. These include practical measurement and the collection, representation and interpretation of data.	Students: • represent and interpret data in graphs. • identify trends and patterns from numerical data.
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: • use interactive resource technology to view, record and analyse information • use a digital camera to record results • use ICT to create multimedia presentations.
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: • ask questions on a TWLH chart and answer them based on investigations • analyse and evaluate secondary sources of information to formulate conclusions • make evidence-based claims about regions that have relatively more earthquake activity.
Ethical behaviour	Students develop ethical behaviour as they explore ethical principles and guidelines in gathering evidence and consider the ethical implications of their investigations on others and the environment.	Students: • ask questions respecting each other's point of view • make reasoned judgments about social, environmental and personal effects of earthquakes.
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: • work collaboratively in teams • listen to and follow instructions to safely complete investigations • participate in discussions • consider the application of science to meet a range of personal and social needs.
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.	• 'Cultural perspectives' opportunities are highlighted where relevant • Important contributions made to science by people from a range of cultures are highlighted where relevant.

All the material in the first two 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.

All three of these are embedded within this unit as described below. For further information see: www.australiancurriculum.edu.au/CrossCurriculumPriorities

Aboriginal and Torres Strait Islander histories and cultures

Primary**Connections** has developed an Indigenous perspective framework that has informed practical reflections on intercultural understanding. It can be accessed at: www.science.org.au/primaryconnections/indigenous

Earthquake explorers focuses on the Western science way of analysing secondary data and trends in order to make evidence-based claims about the causes of earthquakes. Students explore the tectonic plates model of the Earth and resultant explanations for observed changes at the Earth's surface.

Indigenous cultures might have different explanations for the observed phenomenon of earthquakes, or the formation of geological landforms, often referring to Dreamtime. For example, the Awabakal Indigenous people who live in the Newcastle region have a story about a kangaroo which makes the ground shake. Dreamtime stories can be specific to particular people or communities, or can be shared across different groups.

Primary**Connections** recommends working with Indigenous community members to access contextualised, relevant Indigenous perspectives.

Asia and Australia's engagement with Asia

The *Earthquake explorers* unit provides opportunities for students to compare magnitudes of earthquakes in Australia to those of neighbouring Asian countries. Students develop an understanding about why some Asian countries are more prone to higher magnitude earthquakes and appreciate the serious dangers and effects this can have on the people and their environment.

Sustainability

In *Earthquake explorers*, students explore how natural movements of Earth's tectonic plates can result in dramatic effects on people and the environment. Suggested curriculum links provide opportunities for students to develop understanding of how individual and community decisions about materials and building structures can mitigate or contribute to the impact of a natural disaster. This can assist them to develop knowledge, skills and values for making decisions about individual and community actions that contribute to sustainable developments in earthquake-prone regions.

Alignment with the Australian Curriculum: English and Mathematics

Strand	Sub-strand	Code	Year 6 content descriptions	Lessons
English–Language	**Language for interaction**	ACELA1517	Understand the uses of objective and subjective language and bias	1–7
	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	1,2,4,5
		ACELA1526	Understand how to use banks of known words, word origins, base words, suffixes and prefixes, morphemes, spelling patterns and generalisations to learn and spell new words, for example technical words and words adopted from other languages	1–7
English–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	1–7
		ACELY1816	Use interaction skills, varying conventions of spoken interactions such as voice volume, tone, pitch and pace, according to group size, formality of interaction and needs and expertise of the audience	1–7
		ACELY1710	Plan, rehearse and deliver presentations, selecting and sequencing appropriate content and multimodal elements for defined audiences and purposes, making appropriate choices for modality and emphasis	1–7
	Interpreting, analysing, evaluating	ACELY1711	Analyse how text structures and language features work together to meet the purpose of a text	1,2
		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	1,2,4,5
	Creating texts	ACELY1714	Plan, draft and publish imaginative, informative and persuasive texts, choosing and experimenting with text structures, language features, images and digital resources appropriate to purpose and audience	7
Mathematics–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	2,5,6
		ACMSP148	Interpret secondary data presented in digital media and elsewhere	2,5

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

Other links are highlighted at the end of lessons where possible. These links will be revised and updated on the website: www.science.org.au/primaryconnections/curriculum-resources/

Teacher background information

Introduction to earthquakes

The surface of the Earth is changing constantly. There are changes that we can experience directly, such as a meteorite impact and volcanic eruptions. Other changes occur over vast periods of time, such as the development and erosion of mountains and the expansion and disappearance of seas. Earthquakes are sudden events, infamous for their ability to devastate cities in minutes. However, the process that creates the majority of earthquakes is relatively slow.

The outermost shell or crust of the Earth is divided into tectonic plates. These tectonic plates of rock are moving slowly at about the speed that our fingernails grow (0.66 to 8.5 centimetres a year). The tectonic plates forming the lithosphere (*lithos* meaning 'rocky') lie on top of the asthenosphere (*asthenos* meaning 'without strength') and each plate varies in thickness. The thick parts form the continents and thin parts of each plate form the oceanic crust. The rocks of the asthenosphere have a degree of plasticity and are not as rigid as the lithosphere layer above it. These non-rigid rocks flow in convection currents within the Earth and rise after being heated by heat radiating from the Earth's core. They sink after losing this heat on contact with the tectonic plates. Water boiling in a pot has similar convection currents; however, the asthenosphere currents move much more slowly. This movement of the asthenosphere is one of the main reasons why tectonic plates move.

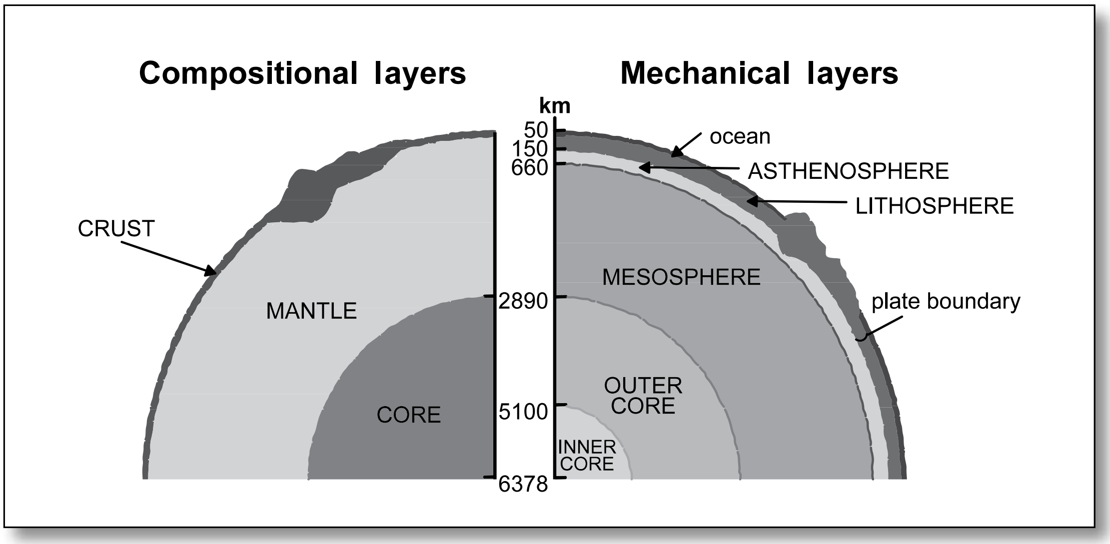


Diagram 1: Two complementary models of the internal structure of the Earth

Each tectonic plate is subjected to a different combination of pressures and movements of the asthenosphere in its region, so they all move in different directions and at different speeds. Two tectonic plates can move away from each other, can collide—with one tectonic plate sliding over the top of the other plate—or can move past each other. When tectonic plates move against each other, they do not slide smoothly. The tectonic plates become stuck, even though they are under pressure to move. The pressure builds up until suddenly the tectonic plates give way and move, releasing the built-up energy. Some of the energy is released in the form of 'seismic waves' (energy that travels in the form of waves through the Earth). Seismic comes from '*seismo*', meaning earthquake. These waves radiate in all directions, including towards the Earth's surface, where they are felt as a shaking or displacement of the ground. We call these events earthquakes. Human activities such as mining and the build-up of large masses of water behind dams can also cause earthquakes, although these are often relatively minor in scale.

Most earthquakes occur on and adjacent to the boundaries of tectonic plates, but sometimes they are felt in the middle of tectonic plates. As tectonic plates continue to move and tectonic plate boundaries change over millions of years, weakened boundary regions become part of the interior of the tectonic plates. These zones of weakness within the continents can cause earthquakes in response to the stresses at the edges of the tectonic plate or inside the Earth's crust.

For further information about earthquakes see the Primary**Connections** Science Background CD and the Primary**Connections** website: www.science.org.au/primaryconnections

Students' conceptions

Taking account of students' existing ideas is important in planning effective teaching approaches which 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.

Some students might think that the surface of the Earth is rigid and unmoving, like a ball or the skin of an orange. Students might think the crust sits on the tectonic plates and is carried along by them. However, it is the crust that is broken up to make the tectonic plates, sitting in pieces like a jigsaw. The Earth has a series of concentric spheres with varying composition and characteristics, for example, part of the mantle is flexible whereas the inner core is rigid.

A common conception held by students is that earthquakes only occur in hot countries where the Sun causes cracks in the ground. Earthquakes actually happen all over the world in hot and cold countries, such as Indonesia and New Zealand. Earthquakes are not caused by the Sun but are in fact caused mostly by the movement of the plates that make up the Earth's surface.

Some students might think that the continents move because they are floating on the sea, as the sea floor is hidden and they think islands have water underneath them. The term 'continental-drift theory' predates 'plate-tectonic theory', since the relative movements of the tectonic plates result in the movement of their 'high ground' (continents). The term 'continental drift' should be avoided as 'drifting' reinforces the notion of floating. Also 'continental' gives the impression that the continents are separate entities, rather than thick parts of the tectonic plates (up to 70km thick compared to 8km thick for oceanic crust). The oceans are actually like very large puddles on top of thinner parts of the crust.

The nature of this topic necessitates the use of secondary data to assist students to build their conceptual understanding. Interesting sources include models, computer graphics, virtual reality, animations, claymation, websites, media archives, drama and literature. Some examples include:

- Community broadcast websites
- Geoscience Australia materials
- Local television and news archives

- National Film and Sound Archive materials
- National Geographic DVDs, such as 'Violent Earth', 'Nature's fury'
- Photo library and photo sharing websites.

This unit requires a collection of images, animations or video footage of the effects of earthquakes. Due to the impact on human life, earthquake footage needs to be carefully selected and focused on the damage caused to buildings, roads and cities.

To access more in-depth science information in the form of text, diagrams and animations, refer to the Primary**Connections** Science Background Resource which has now been loaded on the Primary**Connections** website: www.science.org.au/primaryconnections/science-background-resource

Note that this background information is intended for the teacher only.

Lesson 1 Earthquake encounters

ENGAGE

AT A GLANCE

To capture students' interest and find out what they think they know about how sudden geological changes or extreme weather conditions can affect Earth's surface.

To elicit students' questions about the causes and effects of earthquakes.

Students:

- use visual materials to observe the effects of earthquakes
- create a storyboard using observations from the visual materials
- discuss ideas and questions for a TWLH chart.

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 into account 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 sudden geological changes such as earthquakes can affect Earth's surface, that science can be used to solve problems that directly affect people's lives and communicating their ideas about earthquakes.

ENGAGE

Key lesson outcomes

Science

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

- use visual materials such as photographs, animation or video to observe and describe the effects of earthquakes
- represent what they think they know about the causes and effects of earthquakes.

Literacy

Students will be able to:

- contribute to class discussions about the effects of earthquakes and the resulting changes to the Earth's surface
- use talk to share ideas about earthquakes
- contribute to the class TWLH chart and word wall
- understand the purpose and features of a storyboard
- understand the purpose and features of a glossary.

This lesson also provides opportunities to monitor the development of students' general capabilities (highlighted through icons, see page 6).

Teacher background information

Earthquakes can cause roads and railway tracks to become warped and buildings to topple, sometimes resulting in many deaths. Secondary effects, such as bushfires caused by power lines exposed after the event, add to the damage. The effect of an earthquake depends on where it originates (close to the surface or hundreds of kilometres below the ground) and how much energy was released at the moment of the earthquake (its magnitude, measured by the Richter scale). Some of the energy released by an earthquake travels through the Earth in the form of seismic waves. These seismic waves are responsible for the sensation of shaking at the surface. The effect on humans caused by an earthquake depends on the number of inhabitants in the region and whether the buildings are designed to withstand the stress of the ground moving because of the seismic waves.

Note: Take care while facilitating this lesson as students could have personal experiences of recent catastrophic geological events.

Equipment

FOR THE CLASS

- visual materials (see 'Preparation')
- class science journal
- word wall
- TWLH chart (see 'Preparation')

FOR EACH STUDENT

- science journal

ENGAGE

Preparation

- Read 'How to use a science journal' (Appendix 2).
- Read 'How to use a word wall' (Appendix 3), and prepare a word wall for the class.
- Source visual materials about earthquakes, for example, photos, newspaper clippings, animations, video footage (see 'Introduction to earthquakes' page 8).
- Prepare two columns for the glossary in the class science journal as follows:

***Earthquake explorers* glossary**

Term	Description

Read 'How to use a TWLH chart' (Appendix 4) and prepare a large four-column chart in the class science journal as follows:

***Earthquake explorers* TWLH chart**

What we **think** we know	What we **want** to learn	What we **learned**	**How** we know

- *Optional:* Display the collected visual materials, the class science journal, the word wall and the TWLH chart on an interactive whiteboard or a computer connected to a projector. Check the Primary**Connections** website to see if an accompanying interactive resource has been developed: www.science.org.au/primaryconnections

Lesson steps

1. Introduce students to visual materials of earthquakes and their effects and allow time for students to observe the materials.
2. Explain that students are going to create a storyboard in their science journal. Introduce the class science journal and discuss its purpose and features.

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.

3 Ask students to create a storyboard in their science journal of what they observed in the visual materials and what they think might have caused the damage. Discuss the purpose and features of a storyboard.

Literacy focus

Why do we use a storyboard?

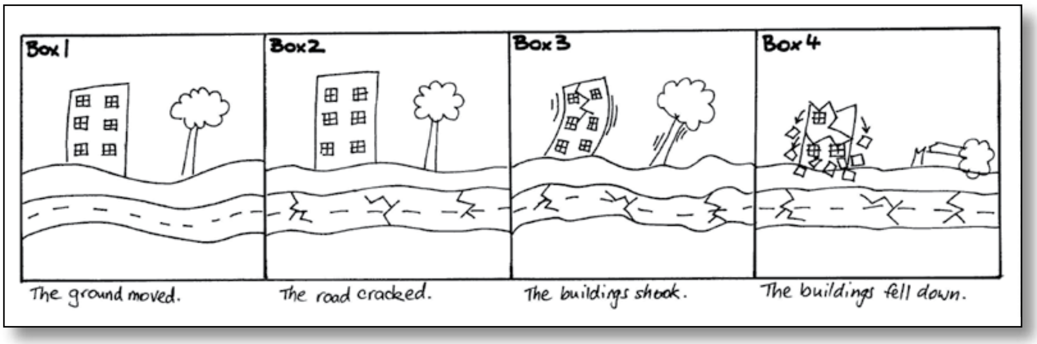
We use a **storyboard** to show the important steps of a process in the order that they happen.

What does a storyboard include?

A **storyboard** includes a title and a series of drawings. Each step in the storyboard is numbered and includes a caption describing the step.

ENGAGE

Encourage students to record in the first one or two boxes what they think caused the damage and in the subsequent boxes the sequence of damage that might have occurred, for example, Box 1—the ground under the road was moving, Box 2—the roads were cracking, Box 3—buildings shaking, Box 4—buildings falling down.



Student's storyboard work sample

Note: This is an opportunity to assess students' prior knowledge of the causes and effects of earthquakes. Some students might be unable to represent what causes an earthquake and might leave the first box blank.

4 Ask students to prepare an oral presentation about their storyboards. As part of their oral presentation, ask students to include answers to the following questions:

- What is the story of your drawings?
- Can you describe what has happened in your storyboard?
- What might have caused this damage?
- Where might you see something like this?
- Do you think an earthquake could have caused this?

Discuss the purpose and features of an oral presentation.

Literacy focus

Why do we use an oral presentation?

We use an **oral presentation** to entertain or provide information for an audience.

What does an oral presentation include?

An **oral presentation** is a speech that has an introduction, main part and conclusion. It might be serious or funny depending on the topic and audience.

5 Introduce the 'Earthquake explorers TWLH chart' and 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 Think we know, What we Want to learn, What we Learned, and How we know. Words or pictures can be used to show our thoughts and ideas.

6 Discuss the first column ('What we Think we know') and invite students to make contributions about what they think they know about earthquakes and record these on the TWLH chart.

Note: In the Engage phase do not provide formal definitions or correct answers as the purpose is to elicit students' prior knowledge of the causes and effects of earthquakes.

7 Introduce the second column of the TWLH chart ('What we Want to learn'). Discuss students' questions about earthquakes and record these in the second column of the TWLH chart.

8 Discuss the purpose and features of a glossary and explain to students that as the unit progresses, they will create a glossary in their science journal.

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.

9 Model how to develop a glossary in the class science journal using the term 'earthquake'. Write the term in the science journal and invite students to describe what they think the term means. Add an agreed description of the term 'earthquake' to the glossary recorded in the class science journal.

Note: Encourage students to revisit the glossary as the unit progresses so they can change or confirm their descriptions of key vocabulary.

10 Introduce the word wall and its title *Earthquake explorers*. Discuss the purpose and features of a word wall.

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 spelt.

What does a word wall include?

A **word wall** might include a topic title or picture and words that we have seen or heard about the topic.

Optional: Develop an earthquake database and 'mobile' of terms with related images.

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

Invite students to contribute words from different languages to the word wall, including local Indigenous names for natural disasters or land formations if possible, and discuss.

12 Allow time for students to use the term 'earthquake' to begin their individual glossary in their science journal.

Curriculum links

History

- Identify and locate a range of relevant sources about other natural disasters, for example, volcanoes and tsunamis.

Lesson 2 Energetic earthquakes

AT A GLANCE

To provide shared experiences of how the effects, magnitude and intensity of earthquakes are measured.

Students:

- read and analyse numerical and factual information about the measurement of earthquakes
- observe the effects of earthquakes and discuss and compare them.

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, for example, 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:

- earthquakes of different magnitude affect the Earth's surface, and how scientific understandings relate to problems in peoples lives such as the amount of damage caused by an earthquake. You will also monitor their developing science inquiry skills (see page 2).

Key lesson outcomes

Science

Students will be able to:

- describe the difference between earthquake magnitude and intensity
- describe and discuss the use of the Richter and Modified Mercalli scales
- analyse numerical and factual information.

Literacy

Students will be able to:

- use talk to discuss their findings with other students
- read, discuss and analyse factual information
- understand the purpose and features of a factual recount
- use a 'Question placemat' to record factual information.

This lesson also provides opportunities to monitor the development of students' general capabilities (highlighted through icons, see page 6).

Teacher background information

Observing

In order to draw reliable conclusions, scientists need accurate data. While direct sensory perception (smell, sight, touch, hearing and taste) is important, the perception depends strongly on the individual. It is also difficult to quantify. Therefore, comparisons between events are difficult. Even if the same observer experiences two earthquakes, they might not be able to accurately compare the two events as memory is unreliable. Records such as photographs and seismograms provide more objective data. These records are only as accurate as the method that was used to acquire them, which is why scientists are able to record increasingly reliable 'observations' with increasingly sophisticated equipment. Scientific instruments extend and improve the human capability to observe and collect data. Thus, science and technology are intimately linked. Science informs technology, but relies on instruments in order to continue to make accurate and reliable observations.

Reporting earthquakes

The energy released at the origin of an earthquake is converted into seismic waves (seismic comes from '*seismo*', meaning earthquake), which travel in all directions away from the source. It is when these seismic waves reach the Earth's surface that an earthquake is felt. The area where an earthquake is recorded is not necessarily where it originated. If an earthquake occurs far below ground, the seismic waves released can dissipate as they travel through the Earth. This results in less shaking than from an earthquake of the same magnitude that occurs closer to the surface.

Two fundamentally different but equally important types of scale are commonly used to describe earthquakes. The amount of energy released by an earthquake and converted into seismic waves is measured on a *magnitude scale*, for example, the Richter scale, while the intensity of shaking occurring at any given point on the Earth's surface is measured on an intensity scale, for example, the Modified Mercalli scale. Ideally, there is only one measure of magnitude for any given earthquake but many different intensities, as the effects of an earthquake depend on the area where it is measured. An earthquake in a city will have a greater effect on humans and infrastructure than an earthquake in an uninhabited area with no roads or buildings.

The Richter scale

The Richter scale is one way to measure the magnitude of an earthquake (the amount of energy released). The Richter scale is calculated by taking logarithms of the height of the seismic waves recorded by the seismograph. This means that a whole-number jump on the Richter scale indicates a tenfold increase in the amplitude of the seismic waves, for example, an earthquake measuring level six on the Richter scale has amplitudes ten times greater than a level five earthquake. Only a percentage of the energy released during an earthquake event is converted into seismic waves. A unit increase in magnitude is equal to a 32-fold increase in the actual energy released by the earthquake. The rest of the energy goes into processes such as heating and deforming rocks. The Richter scale is considered objective because it is based on recordings and measurements. The magnitude does not depend on the area where it is measured, making it a direct characterisation of the earthquake event.

The Modified Mercalli scale

The Modified Mercalli scale is used to measure the intensity of, or destruction caused by, an earthquake. Damage caused by earthquakes can vary from area to area depending on the composition of the ground and the design of structures surrounding the earthquake-affected area. The Modified Mercalli scale uses Roman numerals and is based on people's subjective interpretations. Modified Mercalli scale levels are determined after assessments of the damage are done and witnesses interviewed. An earthquake of low magnitude can rate highly on the Modified Mercalli scale if it hits an area with unstable buildings and causes extensive damage.

Based on interpretations and personal observations, this scale is considered subjective. It describes the effect of the earthquake, which depends on the position of the epicentre of the earthquake and the spread of the seismic waves. There can be several different Modified Mercalli measures for the same earthquake event that is felt in different areas. The Modified Mercalli scale gives us a measure of how the earthquake affected a location, rather than an indication of how much energy was released.

Students' conceptions

A common conception held by students is that earthquakes will not happen in Australia. Earthquakes do occur in Australia although most of these earthquakes are relatively minor in magnitude compared to earthquakes in other countries. The continent of Australia is part of the Australian plate which has its boundaries near countries such as Indonesia and New Zealand. This results in stronger and more frequent earthquakes in these regions. Another common conception is that an earthquake measuring six on the Richter scale has twice the magnitude of an earthquake measuring three. The magnitude of an earthquake is calculated based on a logarithm so that a level three earthquake on the Richter scale has 32 times more energy released than a level two earthquake.

Equipment

FOR THE CLASS	FOR EACH TEAM
• class science journal • word wall • TWLH chart • 1 enlarged copy of ‘Richter scale’ (Resource sheet 3) • 1 enlarged copy of ‘Modified Mercalli scale’ (Resource sheet 4)	• role wristbands or badges for Director, Manager and Speaker • each team member’s science journal • 1 copy of ‘Earthquake hits Newcastle: Eyewitness account’ (Resource sheet 1) per team member • 1 enlarged copy of ‘Question placemat’ (Resource sheet 2) per team member • 1 copy of ‘Modified Mercalli scale’ (Resource sheet 4) (see ‘Preparation’) • 1 envelope

Preparation

- Read ‘How to organise collaborative learning teams’ (Appendix 1). Display an enlarged copy of the team skills chart and the team roles chart in the classroom. Prepare role wristbands or badges and the equipment table.
- Photocopy the ‘Question placemat’ (Resource sheet 2) on to A3 paper for each student.
- Prepare an enlarged copy of ‘Richter scale’ (Resource sheet 3) and ‘Modified Mercalli scale’ (Resource sheet 4).
- Photocopy and cut out each effect on the list of ‘Effects’ of the ‘Modified Mercalli scale’ (Resource sheet 4) for each team. Be sure to shuffle the slips before placing in an envelope. Fold and place the remaining list of ‘Descriptors’ in each team’s envelope.
- Optional: Display ‘Question placemat’ (Resource sheet 2), ‘Richter scale’ (Resource sheet 3) and ‘Modified Mercalli scale’ (Resource sheet 4) on an interactive whiteboard or a computer connected to a projector. Check the Primary**Connections** website to see if an accompanying interactive resource has been developed: www.science.org.au/primaryconnections

Lesson steps

1. Review the previous lesson including the class science journal, glossary and the TWLH chart. Review the first column of the TWLH chart (‘What we Think we know’) and discuss students’ observations of the visual materials in Lesson 1.
2. Explain that students are going to use a factual recount to explore the effects of earthquakes and the ways that scientists measure earthquakes. Discuss the purpose and features of factual recounts.

Literacy focus

Why do we use a factual recount?

We create a **factual recount** to describe things that have happened to us. We can read a **factual recount** to find out about things that have happened to someone else.

What does a factual recount include?

A **factual recount** might include descriptions of how the writer felt and other people who were part of the events. It is often written in past tense.

3 Introduce ‘Earthquake hits Newcastle: Eyewitness account’ (Resource sheet 1) and allow time for students to read the factual recount.

4 Introduce the enlarged copy of the ‘Question placemat’ (Resource sheet 2) and explain that students will record information from the factual recount on the ‘Question placemat’, such as:

- What happened? (There was an earthquake and the ground was shaking and things were falling over.)
- When did it happen? (It happened on 28 December 1989.)
- Where did it happen? (It happened in Newcastle.)
- Who did it affect? (It affected the people who lived in the city.)
- Why did it happen? (There was major damage because the earthquake hit a large city.)

Discuss students’ responses to each question.

5 Ask students if they found out any information from the ‘Earthquake hits Newcastle: Eyewitness account’ factual recount about how scientists measure and record information about earthquakes. Ask questions, such as:

- What damage was caused?
- Do you think the earthquake was strong?
- How would people know the earthquake was strong?
- What could they use to measure the strength of the earthquake?

6 Introduce the enlarged copy of ‘Richter scale’ (Resource 3) to the students. Discuss the descriptions in the first column. Introduce the measurement scale in the second column and relate the numbers to the descriptions. Discuss how the Richter scale is a formal method of measuring the magnitude of earthquakes with readings being taken from a machine called a ‘seismometer’.

7 Discuss the term ‘magnitude’ and add a description to the glossary recorded in the class science journal.

8 Ask students to discuss what information the Richter scale tells us in relation to the ‘Earthquake hits Newcastle: Eyewitness account’ factual recount.

Optional: Ask students to find images of earthquake damage for different levels of the Richter scale.

9 Ask students if the ‘Earthquake hits Newcastle: Eyewitness account’ factual recount provided information about how intense the earthquake was. Discuss the term ‘intensity’ and add a description to the glossary in the class science journal.

EXPLORE

10 Explain that the Modified Mercalli scale is a way that scientists measure the intensity of earthquakes. It includes a list of 'descriptors' matched to a description of intensity of an earthquake. There are 12 levels which progress from minimal to catastrophic intensity.

Note: The Modified Mercalli scale uses Roman numerals.

11 Explain that students will be working in collaborative learning teams to read and discuss the descriptors and effects in the Modified Mercalli scale and will match each effect to a corresponding descriptor.

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 role wristbands or badges to help them (and you) know which role each team member is assigned.

Draw students' attention to the equipment table and discuss its use. Explain that this table is where Managers will collect and return equipment.

12 Form teams and allocate roles. Ask Managers to collect an envelope containing the cut out 'Effects' and a list of 'Descriptors' and allow time for students to complete the activity.

13 Introduce an enlarged copy of 'Modified Mercalli scale' (Resource sheet 4) and compare team responses to the enlarged copy of the Modified Mercalli scale. Ask students if they found any difficulties matching each effect with a corresponding descriptor.

14 Discuss why scientists might use both this scale and the Richter scale to measure earthquakes.

15 Ask students to contribute what they have learned to the third column of the TWLH chart ('What we Learned'). Ask students if they have any further questions for the second column ('What we Want to learn').

16 Update the TWLH chart, word wall and students' individual glossaries in their science journal.

Curriculum links

English

- Create a mix and match flip book using the Modified Mercalli scale.

Asia and Australia's engagement with Asia

- Discuss and compare traditional and modern housing from different countries in the Asia-Pacific region and discuss their advantages and disadvantages, in particular whether they are appropriate for earthquake-prone areas.

Earthquake hits Newcastle: Eyewitness account

Name: ____________________ **Date:** ____________

On Thursday 28 December 1989, an earthquake hit the city of Newcastle. Eyewitness reports from the area have estimated that the area shook for around five seconds and caused extensive damaged to buildings in the area.

Local authorities have confirmed that over 40,000 buildings have been damaged or destroyed. Shopkeepers and residents have been shocked by the damage caused, with many buildings showing signs of minor damage and others with severe damage. Some residents stated that their neighbourhoods looked like a cyclone had hit it but most tuned into local radio stations to find out the real cause of the destruction.

One shopkeeper was saddened to report that most of the damage seemed to be to older buildings, some of which were over 100 years old, with a long history in the community.

A resident has told how she was talking to a friend and all of a sudden felt the ground shaking with glassware and crockery rattling and falling off the shelves. Other residents have commented on how cracks started to appear in the walls of their homes.

Despite the extensive damage to buildings, major infrastructure, such as railway tracks and telephone lines were not badly damaged.

A local seismologist has reported that the earthquake measured 5.6 on the Richter scale. He has also commented that Australia experiences strong earthquakes like these around every 18 months but they rarely happen in populated areas and have little effect on people and communities. Because this particular earthquake hit a city with buildings and infrastructure, it was estimated to have caused about $4 billion damage.

Members of nearby towns have reported to have felt the shaking, with scientists confirming that the shaking was felt up to 600 kilometres away from the epicentre of the earthquake.

Question placemat

Newcastle earthquake

Name: ____________________

Date: ____________________

What?

Where?

When?

Who?

Why?

Richter scale

Description	Richter magnitudes
Micro	Less than 2.0
Very minor	2.0–2.9
Minor	3.0–3.9
Light	4.0–4.9
Moderate	5.0–5.9
Strong	6.0–6.9
Major	7.0–7.9
Great	8.0–8.9
Rarely	9.0–9.9
Meteoric	10.0+

Modified Mercalli scale

Descriptors	Effects
I. Instrumental	Not felt, except by very few people under especially favourable conditions.
II. Feeble	Felt by only a few people at rest, especially on upper floors of buildings.
III. Slight	Felt quite noticeably by people indoors, especially on the upper floors of buildings. Many do not recognise it as an earthquake. Stationary motor cars can rock slightly.
IV. Moderate	Felt indoors by many, outdoors by few; some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Stationary motor cars rock noticeably. Dishes and windows rattle alarmingly.
V. Rather strong	Felt by nearly everyone; many awakened. Some dishes and windows broken. Unstable objects overturned.
VI. Strong	Felt by all; many frightened and run outdoors, walk unsteadily. Windows, dishes, glassware broken; books off shelves; some heavy furniture moved or overturned.
VII. Very strong	Difficult to stand; furniture broken. Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken. Noticed by people driving motor cars.
VIII. Destructive	Damage slight in specially designed structures; considerable in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls.
IX. Ruinous	General panic; damage considerable in specially designed structures, well-designed frame structures thrown out of plumb; partial collapse. Buildings shifted off foundations.
X. Disastrous	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundation. Railway tracks bent.
XI. Very disastrous	Few, if any, masonry structures remain standing. Bridges destroyed. Railway tracks bent greatly.
XII. Catastrophic	Total damage: almost everything is destroyed. Objects thrown into the air. The ground moves in waves or ripples. Large amounts of rock can move.

Lesson 3 Unearthing quakes

AT A GLANCE

To provide students with hands-on, shared experiences of modelling the changes to the Earth's surface which cause earthquakes.

Session 1 Modelling earthquakes

Students:

- use models to explore the Earth's tectonic plates and the plate movement that results in earthquakes
- discuss the use of scientific models to represent a scientific idea
- use plasticine and an egg to represent their understanding of tectonic plate movement.

Session 2 Interior insights (*Optional*)

Students:

- use an egg as a model of the internal structure of the Earth
- compare the layers of the egg with the layers of the Earth.

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:

- observable changes at the Earth's surface can be due to geological changes such as the relative movement of tectonic plates, and gathering evidence using models to develop explanations. You will also monitor students developing science inquiry skills (see page 2).

Key lesson outcomes

Science

Students will be able to:

- describe tectonic plate movement
- represent their understanding of tectonic plate movement using a plasticine model
- discuss and compare the layers of the egg model with the layers of the Earth.

Literacy

Students will be able to:

- use talk to describe tectonic plate movement
- discuss and describe the layers of the egg model and the layers of the Earth
- contribute to a class discussion about tectonic plates.

This lesson also provides opportunities to monitor the development of students' general capabilities (highlighted through icons, see page 6).

Teacher background information

The structure of the Earth

The Earth is a series of concentric near-spheres. There are two different ways of describing the Earth's structural spheres, depending on which differences are considered important. The first version, the model of compositional layers, is based on the composition of the rocks of each level. It divides the Earth into three spheres: crust, mantle and core (see Diagram 1, 'Introduction to earthquakes'). The model of the compositional layers of the interior of the Earth is based on observations of meteoroids that have resulted from collisions between planets. Scientists also use what they know of the properties of the different minerals, such as density and different melting points, to determine the composition of the Earth.

The second version, the model of mechanical layers, is based on the physical properties of the rocks. The lithosphere (composed of the crust's plates and the top part of the mantle) is the hard, rocky shell. It is the lithosphere that is broken up into tectonic plates. The asthenosphere is the more flexible part of the mantle, which flows in very slow-moving convection currents. Underneath is the mesosphere, which is more rigid. The core is divided into a liquid outer core and a solid inner core (see Diagram 1). The properties of the rocks are deduced by looking at how seismic waves travel through them, for example, there is a type of seismic wave that does not travel through liquids. By analysing data from around the world from the same earthquake and comparing these with world-wide data of other earthquakes in other locations, seismologists build models of the interior of the Earth.

Tectonic plates

The theory of plate tectonics was developed during the first half of the twentieth century and gained acceptance in the late 1960s. The theory proposes that the lithosphere is broken into tectonic plates that float on a hot, flexible rock layer beneath the asthenosphere. The tectonic plates are in slow and constant motion due to the convection currents in the asthenosphere. Each tectonic plate has a unique combination of characteristics and local conditions in the asthenosphere, therefore the tectonic plates move in different directions, and at different speeds.

There are three basic ways the tectonic plates move in relation to each other. They can:

- collide (converge)
- spread apart (diverge)
- slide past each other (transform).

Note: Tectonic plates can slide past each other in opposite directions, or they can be moving in the same direction and friction is created by one tectonic plate moving faster than the other.

Rocks are not smooth, so when tectonic plates slide against each other they can lock together. The tectonic plates are still under pressure to move, so the pressure builds up. The pressure continues to build up until the system cannot store any more energy and something gives at one point (the focus). The stored energy is released suddenly and tectonic plates move, break, rebound or buckle, and produce heat. Some of the energy is released in the form of seismic waves that travel in all directions through the Earth. When these seismic waves reach the surface of the Earth, the shaking associated with an earthquake is experienced. The point on the Earth directly above the origin (the focus) of the earthquake is called the epicentre.

The use of scientific models

The physical world is very complicated, with millions of variables and many unknowns. Scientists use models to help engage with a concept or to produce testable hypotheses. Often the model is a simplified version of reality, and the ability of the model to fit the actual observations tells scientists whether their simplifications were justified or not. Models can be expressed physically, such as plastic replicas of a human heart; by the written word, for example, saying that DNA is like a computer program; by a mathematical formula; or by combinations of these. These models are all expressions of a current theory to be tested.

Although a model might be an expression of an idea, rather than an actual structure or process, a good model accounts for that which can be observed. Some models account well for some observations, but not all, whereas another model might explain different observations. For example, the model of the compositional layers of the Earth is a chemical division of the Earth into crust, mantle and core. This model accounts for inferences about compositions at different depths. The model of the mechanical layers of the Earth uses the observations of seismic waves to distinguish layers with different properties. Hence each model is based on a different set of observations, and can explain different things. Models have limitations to their effectivenesss of explanation and representation. A scientist will acknowledge and describe the limitations of any scientific model devised. Information gathered from experiments can support or discredit a scientific model.

Using scientific models to represent scientific phenomena can assist students to develop their understanding. Effective teaching includes discussion of the way in which models represent a concept and ways in which it might not.

Session 1 Modelling earthquakes

Equipment

FOR THE CLASS

- class science journal
- word wall
- TWLH chart
- 3 sets of 2 plasticine pieces (see 'Preparation')
- several small blocks (eg, wooden or plastic)

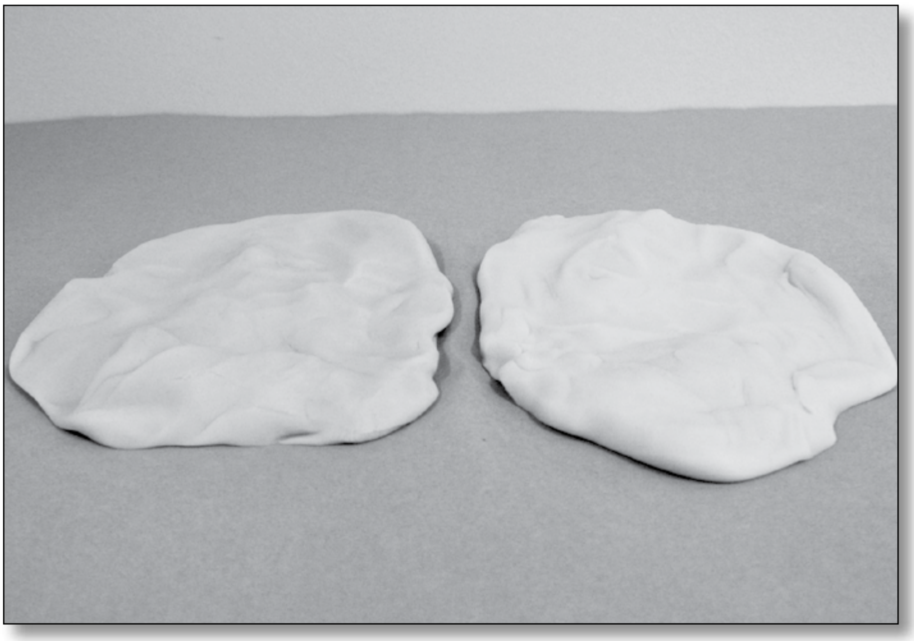
FOR EACH TEAM

- role wristbands or badges for Director, Manager and Speaker
- each team member's science journal
- 1 hard-boiled egg with cracked shell (see 'Preparation')
- *Optional*: magnifying glass, digital camera or microscopic camera

EXPLORE

Preparation

- Prepare three sets of two plasticine pieces. Flatten each piece of plasticine to make a 20 cm x 10 cm piece approximately 1.5cm thick. Plasticine pieces with rough edges and differing thicknesses within each piece create a more accurate model of tectonic plates.



Sample plasticine pieces

- Pre-crack the shell of one hard-boiled egg into approximately seven pieces for each team.

SAFETY

Some students might be allergic to eggs. Students will not be ingesting eggs but might suffer from allergies caused by inhalation and touch.

Lesson steps

1 Review the previous lesson including the class science journal, glossary and the TWLH chart.

2 Introduce the students to three sets of two flat plasticine pieces (see 'Preparation'). Invite two students to gently push one set of plasticine pieces together. Ask the class to observe and describe changes at the edges of the plasticine pieces.

3 Invite another two students to gently pull apart the second set of plasticine pieces.

Ask the class to observe and describe what happens to the plasticine pieces.

4 Invite another two students to gently move the third set of plasticine pieces by sliding them past each other. Ask the class to observe and describe the changes to the edges of the plasticine pieces. Discuss and compare what happened to the plasticine pieces in each movement.

5 Explain to students that they are now going to place a set of stacked blocks on top of the plasticine at the point where the two pieces meet. The blocks will represent a building and demonstrate what can happen to it during an earthquake. Ask students to observe what happens to the building when they repeat each movement and discuss how this movement models what happens when parts of the Earth's surface move, causing earthquakes.

6 Explain to students that scientists use models to help them represent and observe scientific ideas. Ask students if they could think of a model to represent the Earth. Discuss why an egg might or might not be a good model for the Earth, for example, round-ish shape but it has no features to represent mountains or rivers.

7 Explain that students will be working in collaborative learning teams to model changes to the Earth's surface using a cracked hard-boiled egg as a model of the Earth. Explain that team members will take turns to complete one movement each:

- Gently push two parts of the cracked shell together. Discuss the changes that occurred at the edges of the cracked shell and how this could be similar to what happens on the surface of the Earth. Ask students to use drawings and writing to record their observations in their science journal.
- Gently spread two parts of the cracked shell apart and observe what happens. Discuss the changes that occurred at the edges of the cracked shell and how this could be similar to what happens on the surface of the Earth. Ask students to use drawings and writing to record their observations in their science journal.
- Gently slide two parts of the cracked shell past each other and observe what happens. Discuss the changes that occurred at the edges of the cracked shell and how this could be similar to what happens on the surface of the Earth. Ask students to use drawings and writing to record their observations in their science journal.

Optional: Use a magnifying glass, digital camera or microscope to magnify the edges of the cracked shell and to see the changes that occur when parts of the shell are moved.

8 Form teams and allocate roles. Ask Managers to collect team equipment.

Note: Remind team members to handle the egg gently.

9 Allow time for teams to explore the cracked egg shell and how it can model changes to the Earth's surface.

10 Introduce the term 'tectonic plate' by explaining that the pieces of egg shell represent the tectonic plates that make up the Earth's surface. Discuss how the Earth's surface is separated into tectonic plates. Ask questions such as:

- What happens at the edges of the tectonic plate (piece of shell) when it is pushed together, pulled apart or slid past another plate?
- When one tectonic plate (piece of shell) moves, what do the other plates do?
- In how many different directions can the tectonic plate move?
- What happens to the gaps around each tectonic plate if I push one plate away from, or towards another plate?

Note: At this stage, students might discuss the difference between continents and tectonic plates (refer to 'Students' conceptions' in 'Introduction to earthquakes').

11 Ask students to contribute what they have learned to the third column of the TWLH chart ('What we Learned'). Ask students if they have any further questions for the second column ('What we Want to learn').

12 Update the TWLH chart, word wall and students' individual glossaries in their science journal.

Note: Store hard-boiled eggs for Session 2.

Session 2 Interior insights (*Optional*)

Equipment

FOR THE CLASS

- class science journal
- word wall
- TWLH chart
- 1 knife
- 1 enlarged copy of 'On the inside' (Resource sheet 5)

FOR EACH TEAM

- role wristbands or badges for Director, Manager and Speaker
- each team member's science journal
- 1 half of a hard-boiled egg with cracked shell (see 'Preparation')

EXPLORE

Preparation

SAFETY
- Use the knife to cut the cracked, hard-boiled eggs from Session 1 into halves. It is important that each layer of the egg can be easily observed.

SAFETY
- Some students might be allergic to eggs. Students will not be ingesting eggs but might suffer from allergies caused by inhalation and touch.

Lesson steps

1. Review the previous lesson including the class science journal, glossary and the TWLH chart.
2. Explain that students will be working in collaborative learning teams to observe the inside of the hard-boiled egg and discuss ways that it could be used as a model of the Earth.
3. Form teams and allocate roles. Ask Managers to collect half of a hard-boiled egg (see 'Preparation').

   Note: Remind students to handle the egg carefully.
4. Allow time for each team to observe the layers of the egg and discuss their observations with another team. Ask students if they were using the egg to represent the Earth, what each layer would represent. Encourage students to provide reasons for their responses.
5. Introduce the enlarged copy of 'On the inside' (Resource sheet 5) and discuss the purpose and features of a cutaway diagram.

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 Ask students to compare the layers of the egg with those of the Earth. Ask questions such as:

- How would you describe the egg white? (It is flexible and not rigid.)
- How would you describe the egg yolk? (It is more solid than the egg white.)
- What are some of the similarities between the egg and the diagram of the Earth? (The egg has layers and so does the Earth.)
- What are some of the differences between the egg and the diagram of the Earth? (The egg is not the same shape as the Earth.)

Record students' responses in the class science journal.

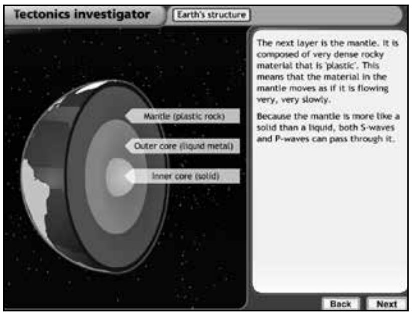
7 Update the TWLH chart, word wall and students' individual glossaries in their science journal.

EXPLORE

Curriculum links

Science

Further explore the internal structure of the Earth:



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The Le@rning Federation

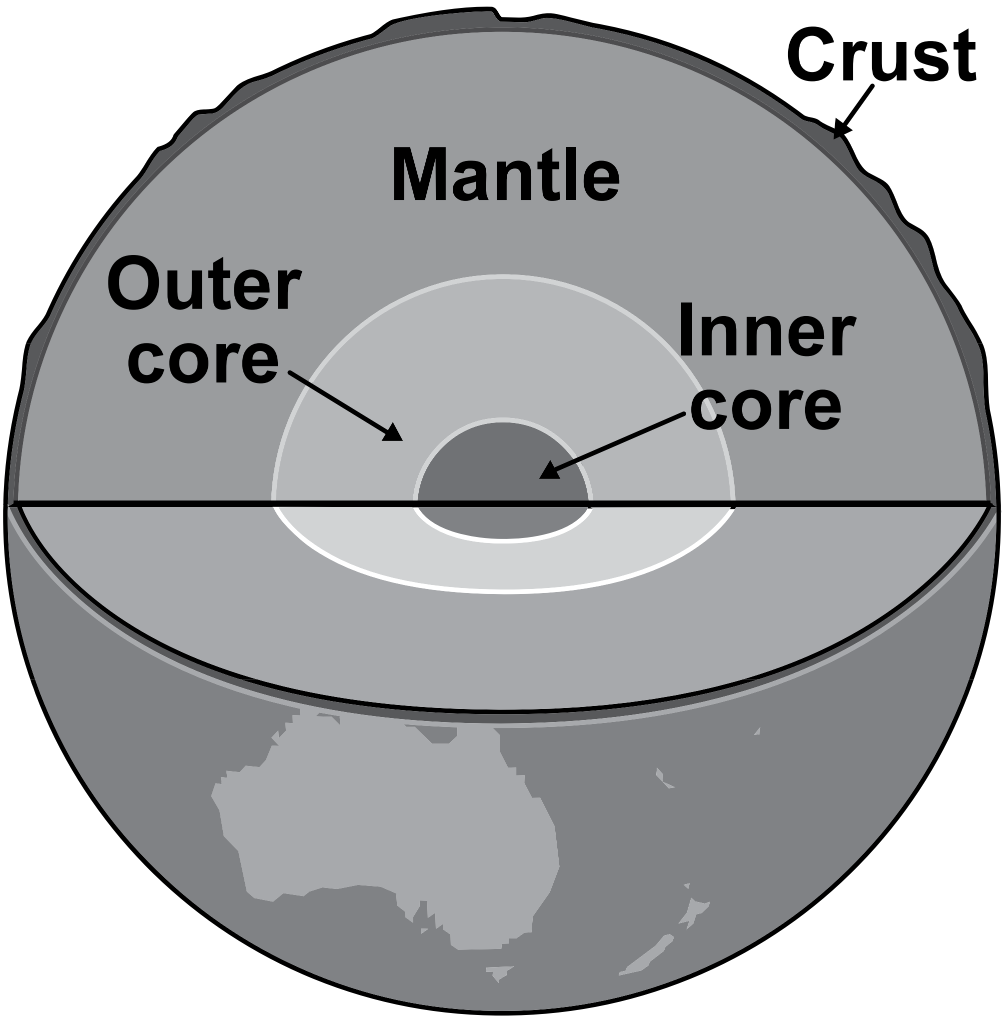
(www.thelearningfederation.edu.au)

Tectonics investigator: Earth's structure, Curriculum Corporation, The Le@rning Federation learning object L5827.

Students investigate, analyse and interpret a model of the Earth's internal structure through animations and scientific data. In a jigsaw activity, students fit the Earth's tectonic plates together and then identify characteristics of the plates.

Note: Students might require support with this learning object as it is designed for Years 7–10.

On the inside



Cutaway diagram of the Earth

Lesson 4 Explaining earthquakes

EXPLAIN

AT A GLANCE

To support students to represent and explain their understanding of changes to the Earth's surface which causes earthquakes.

To introduce students to current scientific views about earthquakes and tectonic plates.

Session 1 Plates on the move

Students:

- read and discuss a factual text about earthquakes
- use plasticine and descriptions to represent their understanding of tectonic plate movement.

Session 2 Changes over time

Students:

- discuss the movement of tectonic plates and suggest reasons for movement.

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.

Assessment focus

Formative assessment is an ongoing aspect of the *Explain* 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 geological changes such as earthquakes can suddenly affect Earth's surface but can be due to slow processes such as tectonic plate movement, and gathering evidence using models to develop explanations. You will also monitor students' developing science inquiry skills (see page 2).

You are also able to look for evidence of students' use of appropriate ways to represent what they know and understand about earthquakes and the Earth's surface, and give them feedback on how they can improve their representations.

Key lesson outcomes

Science

Students will be able to:

- review their understanding of earthquakes and plate movement using factual texts
- make and use a plasticine model to explain tectonic plate movement.

Literacy

Students will be able to:

- use written language and models to demonstrate their understanding of earthquakes and tectonic plate movement
- use scientific language to describe three types of plate movement
- understand the purpose and features of factual texts
- understand the purpose and features of a timeline.

This lesson also provides opportunities to monitor the development of students' general capabilities (highlighted through icons, see page 6).

Teacher background information

Geological time

Geological time helps scientists to understand the geological processes and events that have occurred during the history of the Earth. Though the Earth's history spans billions of years, such large time frames are often abstract and quite removed from the use of time in our everyday lives. To gain an understanding of time, we often use properties as an analogy, such as angles, volume and length, to give us an idea of how much time has elapsed. By observing a rolled out toilet roll with indicators marking significant events, we can begin to compare recent time scales to other events in the history of the Earth.

Tectonic plate movement

The term 'continental drift' is a misleading term. Continents are not separate entities; they are the parts of the tectonic plate that are thicker, and are therefore not submerged by oceans. When sea levels change, the coastal contours of continents change. During the last Ice Age, sea levels dropped and the lands of New Guinea and Australia were connected by a land bridge. Some continents are spread across several tectonic plates; some tectonic plates do not have continents at all (see 'Diagram 2').

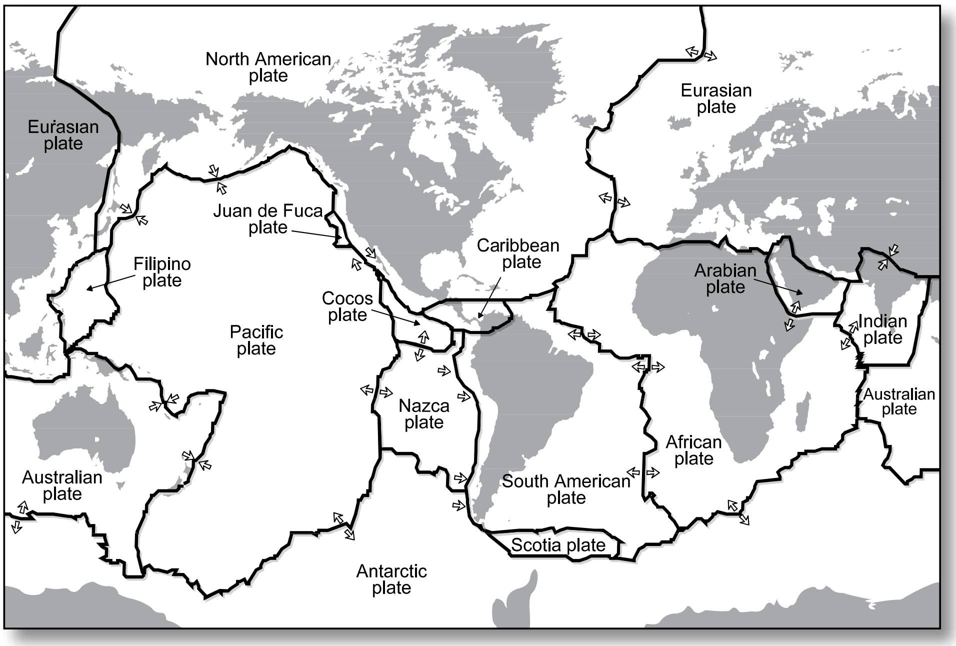


Diagram 2: Map of the world including the main tectonic plates

Earthquake disaster

Location plays a large role in the potential for an earthquake disaster. As 90 per cent of earthquakes occur along tectonic plate boundaries (see the thick, black lines on Diagram 2), these are the sites that have the greatest risk of experiencing earthquakes with the potential to destroy cities. Often these areas have cities built to withstand lower-magnitude earthquakes that would cause damage in other zones of the world. Not all earthquakes occur along the tectonic plate boundaries. An earthquake in 2001 in Gujarat, India, was located well away from the nearest tectonic plate boundary, and its cause is not well understood. Rated at Richter 7.9, it hit an area that was not prepared and caused extensive devastation, including tens of thousands of deaths and billions of dollars of property damage. These 'intra-tectonic plate' earthquakes are thought to be due to zones of weakness inside a tectonic plate, responding to pressure placed on the outside of the plate. The entire continent of Australia is in the middle of a tectonic plate, with no part of it near a major tectonic plate boundary. Australia is reasonably safe from high-magnitude earthquakes (above Richter 5), but they still occur from time to time, for example, the Newcastle earthquake in 1989, measuring 5.6 on the Richter scale.

EXPLAIN

Session 1 Plates on the move

Equipment

FOR THE CLASS

- class science journal
- word wall
- TWLH chart
- 1 overhead transparency copy of ‘Plates on the move’ (Resource sheet 6)
- *Optional*: video camera or digital camera

FOR EACH TEAM

- role wristbands or badges for Director, Manager and Speaker
- each team member’s science journal
- 1 copy of ‘Plates on the move’ (Resource sheet 6) per team member
- 2 plasticine pieces per team member
- toothpicks
- several small pieces of cardboard (7 cm x 4 cm approximately)

Preparation

- Photocopy ‘Plates on the move’ (Resource sheet 6) onto an overhead transparency and make paper copies for each student.
- Prepare two plasticine pieces for each student. Flatten each piece of plasticine to make a 10 cm x 10 cm piece approximately 1.5 cm thick. Plasticine pieces with rough edges and differing thicknesses within each piece create a more accurate model of tectonic plates.
- *Optional*: Ask students to flatten and shape their plasticine pieces before modelling their tectonic plate movement.
- *Optional:* Display the ‘Plates on the move’ (Resource sheet 6) on an interactive whiteboard or a computer connected to a projector. Check the Primary**Connections** website to see if an accompanying interactive resource has been developed: www.science.org.au/primaryconnections

Lesson steps

1. Review the previous lesson including the class science journal, glossary and the TWLH chart.
2. Ask students, as a class or individually, to read through the factual text ‘Plates on the move’ (Resource sheet 6), highlighting any key words, dates or names that could be relevant and/or important in explaining how earthquakes occur, including how they are linked to tectonic plate movement. Discuss the purpose and features of a factual text.

Literacy focus

Why do we use a factual text?

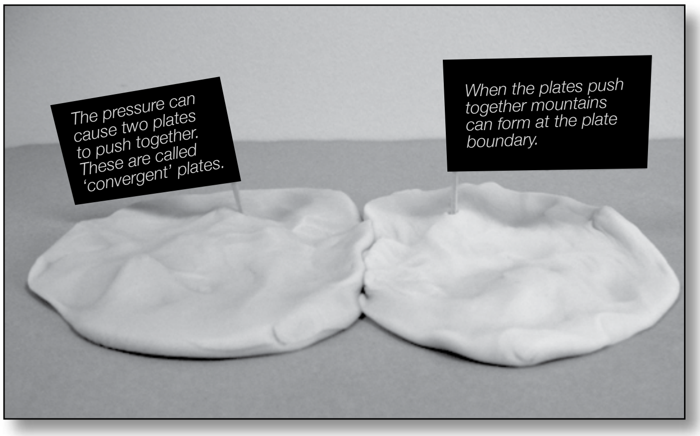
We use a **factual text** to inform, teach or persuade someone reading it. We can read a **factual text** to collect information.

What does a factual text include?

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

3 Based on the information read in 'Plates on the move' (Resource sheet 6), discuss the terms 'convergent', 'divergent' and 'transform'. Add each term with a brief description to the class word wall and glossary recorded in the class science journal.

4 Explain that students will be working in collaborative learning teams to create a representation of tectonic plate movement. Each team member will create one of the three tectonic plate movements using plasticine. Students will add captions, using cardboard on toothpicks, to name and describe their understanding of how each plate moves and what happens at the plate boundary during this movement and how this might cause earthquakes.



Student model of plate movement

Optional: Ask each team to create a video, photo sequence, claymation or animation of each type of tectonic plate movement. Use audio or captions to describe each plate movement, its effect on the Earth's surface and how this might cause earthquakes.

5 Form teams and allocate roles. Ask managers to collect team equipment. Allow time for each team member to create the plate movement using the plasticine.

6 Select teams to present each of their tectonic plate movement models to the class and describe how each plate moves, how this affects the Earth's surface and how this movement might cause earthquakes.

7 Review the use of models in science, including ways in which they represent the concept and ways in which they might not (see Lesson 3, 'Teacher background information').

8 Review the third and fourth columns of the TWLH chart and add any further contributions.

9 Update the TWLH chart, word wall and students' individual glossaries in their science journal.

Plates on the move

Name: ______________________________ **Date:** ________________

When the Earth formed billions of years ago, it was very, very hot. Slowly, it cooled and the outside of the Earth became hard and rocky while parts of the inside remained hot. This hard and rocky surface is broken into large sections and several smaller ones. These sections are called **tectonic plates** and they move! They move very, very slowly—about as fast as your fingernails grow. These plates move because of the hot, moving layer beneath them.

The tectonic plates are thick in some areas and thin in other areas. The thick parts are called continents, which include different countries. The thin parts of the plates form the ocean floor.

Plates can move in many different directions and at different speeds. Two plates that are next to each other can move in three different ways at the plate boundaries.

Plates can move apart

Pressure that builds up in the middle of the Earth can push two plates and cause them to spread apart. This plate movement is called '**divergent**'. This usually happens under the ocean because the plate is thinner there.

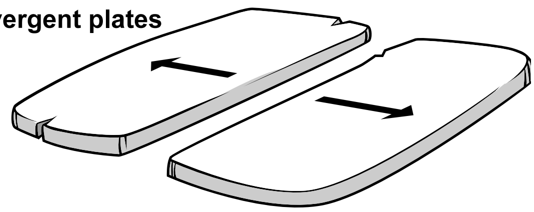
Plates can push together

Pressure can cause two plates to push together. This plate movement is called '**convergent**'.
Over a very long time, this pushing can create mountains.

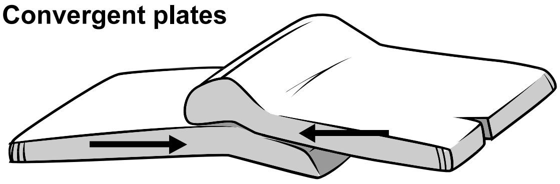
Plates can slide past each other

Plates can move past each other in opposite directions, or they can move in the same direction at different speeds. The plates are pushed together strongly so, as they move past each other, a lot of pressure builds up. An earthquake happens when this pressure is released. This plate movement is called '**transform**'.

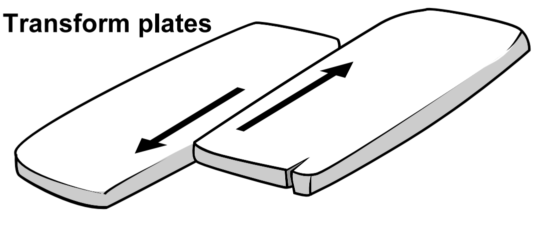
Divergent plates



Convergent plates



Transform plates



Session 2 Changes over time

Equipment

FOR THE CLASS

- class science journal
- each student's science journal
- word wall
- TWLH chart
- 1 overhead transparency copy of 'Map of the continents' (Resource sheet 7)
- 1 overhead transparency copy of 'Map of the plate boundaries' (Resource sheet 8)
- 1 overhead transparency copy of 'Continent formation: 160 million years ago' (Resource sheet 9)
- 1 overhead transparency copy of 'Continent formation: 60 million years ago' (Resource sheet 10)
- coloured overhead markers
- overhead projector
- 1 roll of toilet paper (see 'Preparation')
- 5 self-adhesive notes (see 'Preparation')

EXPLAIN

Preparation

- Photocopy the following onto overhead transparencies:
  - 'Map of the continents' (Resource sheet 7)
  - 'Map of the plate boundaries' (Resource sheet 8)
  - 'Continent formation: 160 million years ago' (Resource sheet 9)
  - 'Continent formation: 60 million years ago' (Resource sheet 10).
- Prepare the roll of toilet paper as follows:
  - Count the first 40 sheets and mark with a coloured marker or self-adhesive tape
  - Continue counting and mark the 80th, 120th and 160th sheet.
  - Mark three of the self-adhesive notes: '160 million years ago', '60 million years ago' and 'Present time'.
- *Optional:* Display the 'Map of the continents' (Resource sheet 7), 'Map of the plate boundaries' (Resource sheet 8), 'Continent formation: 160 million years ago' (Resource sheet 9) and 'Continent formation: 60 million years ago' (Resource sheet 10) on an interactive whiteboard or a computer connected to a projector. Check the Primary**Connections** website to see if an accompanying interactive resource has been developed: www.science.org.au/primaryconnections

Lesson steps

1 Review the previous session including the class science journal, glossary and the TWLH chart. Ask students questions such as:
   - What do we know about the causes of earthquakes?
   - What do we know about the effects of earthquakes?
   - What do we know about observing and measuring earthquakes?

2 Introduce the 'Map of the continents' (Resource sheet 7) overhead transparency and discuss each of the continents.

3 Introduce the 'Map of the plate boundaries' (Resource sheet 8) overhead transparency and place over the 'Map of the continents' transparency. Discuss how each plate moves and has thick and thin parts (the thick parts make up the continents while the thin parts form the ocean floor). Discuss how Australia is one country that is situated on one tectonic plate, not across tectonic plate boundaries.

4 Introduce the 'Continent formation: 160 million years ago' (Resource sheet 9) overhead transparency and ask students what they think is represented in the resource sheet. Explain that many millions of years ago, the continents were not in the same place they are today. Discuss where some of the continents were situated 160 million years ago. Ask students if they can identify which land mass might be Australia.

5 Introduce the 'Continent formation: 60 million years ago' (Resource sheet 10) overhead transparency and ask students to describe what has happened to the continents in this resource sheet. Discuss how each land mass has moved. Ask students to identify where Australia has moved to in relation to the other land masses.

6 Place the 'Continent formation: 60 million years ago' transparency over 'Continent formation: 160 million years ago' transparency and compare the movement of continents over 100 million years.

Optional: Source and allow the students to view an animation of continent formation.

7 Review the 'Map of the plate boundaries' (Resource sheet 8) and discuss the type of plate movement that occurs at the edges of the Australian plate indicated on the map. Ask students to use their understanding of plate movement to offer possible explanations about why Australia has moved over millions of years.

8 Ask students if they know of any other events that occurred many millions of years ago, for example, extinction of dinosaurs or the first record of modern humans. Explain to students that we can begin to understand such large durations of time by comparing events on a timeline. Discuss the purpose and features of a timeline.

Literacy focus

Why do we use a timeline?

We use a **timeline** to show events in the order they happened.

What does a timeline include?

A **timeline** includes a heading and units of time. Each event is indicated on the timeline using words or symbols.

9 Introduce the toilet roll to the class and explain that the class will roll it out to create a timeline. Explain to students that a roll of toilet paper is being used to represent a long span of time.

10 Roll out the toilet paper to the fourth mark. Explain to the class that there are 160 sheets in the rolled out toilet paper. Discuss each of the marked points on the toilet paper, asking questions such as:

- How many sections are there between the marked points? (Four.)
- What fraction of the toilet paper does each section represent? (One quarter.)
- If there are 160 sheets, how many sheets are in each section? (40 sheets per section.)

11 Discuss that the 160th sheet represents 160 million years ago and the edge of the 1st sheet represents present time. Explain that the Earth was formed billions of years ago and this time is represented by the paper still rolled up on the toilet roll. Select students to use self-adhesive notes to mark '160 million years' and 'Present time' on the toilet paper, placing a copy of 'Continent formation: 160 million years ago' (Resource sheet 9) and 'Map of the continents' (Resource sheet 7) next to the corresponding marks. Ask students to use the marked points on the toilet paper to estimate where the 60th sheet might be on the timeline. Discuss students' estimates and use a self-adhesive note to mark '60 million years ago', placing a copy of 'Continent formation: 60 million years ago' (Resource sheet 10) next to the mark. Discuss the time taken for the continents to move from their positions at 160 million years ago to present time.

12 Ask students to estimate what point on the toilet-paper timeline might represent when the extinction of dinosaurs occurred and place their finger on the corresponding point. Explain that dinosaurs became extinct 65 million years ago and place a self-adhesive note with the label 'Dinosaurs extinct' on the 65th sheet.

13 Discuss that evidence of modern humans was recorded on the Earth around 10,000 years ago and that modern humans are only relatively 'new' in the history of the Earth. Use a coloured marker to mark the front edge of the 1st sheet. Place a self-adhesive note with the label 'Modern humans' next to the mark.

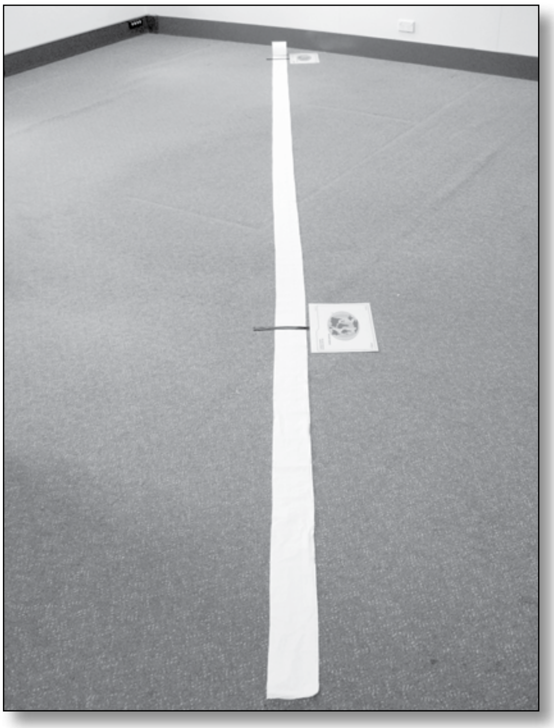


Photo of rolled out toilet paper

14 Ask students to use the indicators on the toilet paper timeline to discuss and compare the difference in time between 160 million years ago, 60 million years ago and present time. Discuss how plate movement and other geological events take place over a very long period of time.

15 Update the TWLH chart, word wall and students' individual glossaries in their

science journal.

Curriculum links

Science

- Further explore how sudden geological changes can affect the surface of the Earth, for example, recognise that earthquakes can cause tsunamis.

Mathematics

- Find a simple fraction of 160 million years where the result is a number of years.

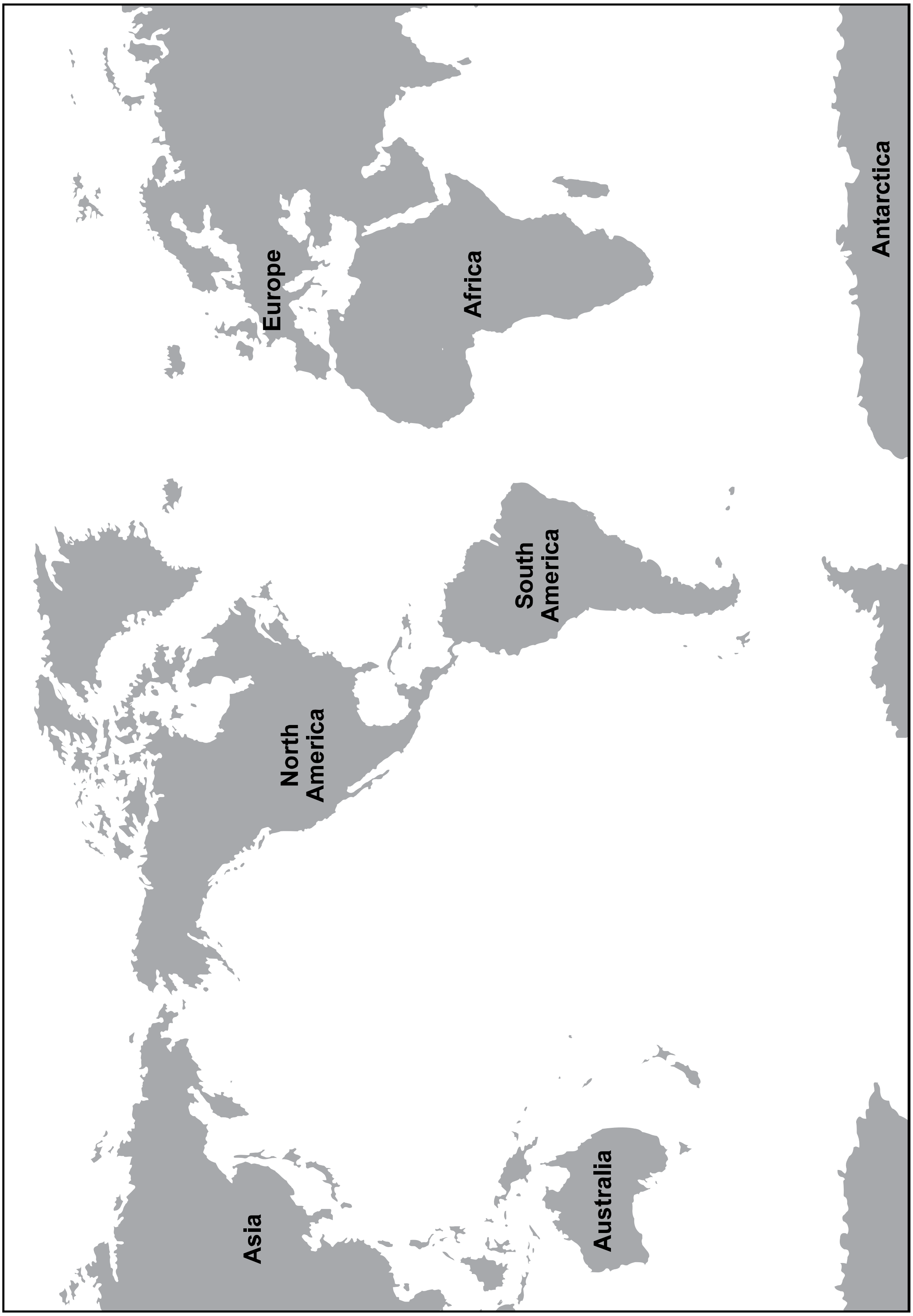
History

- Add other major geological or natural disaster events to timeline.

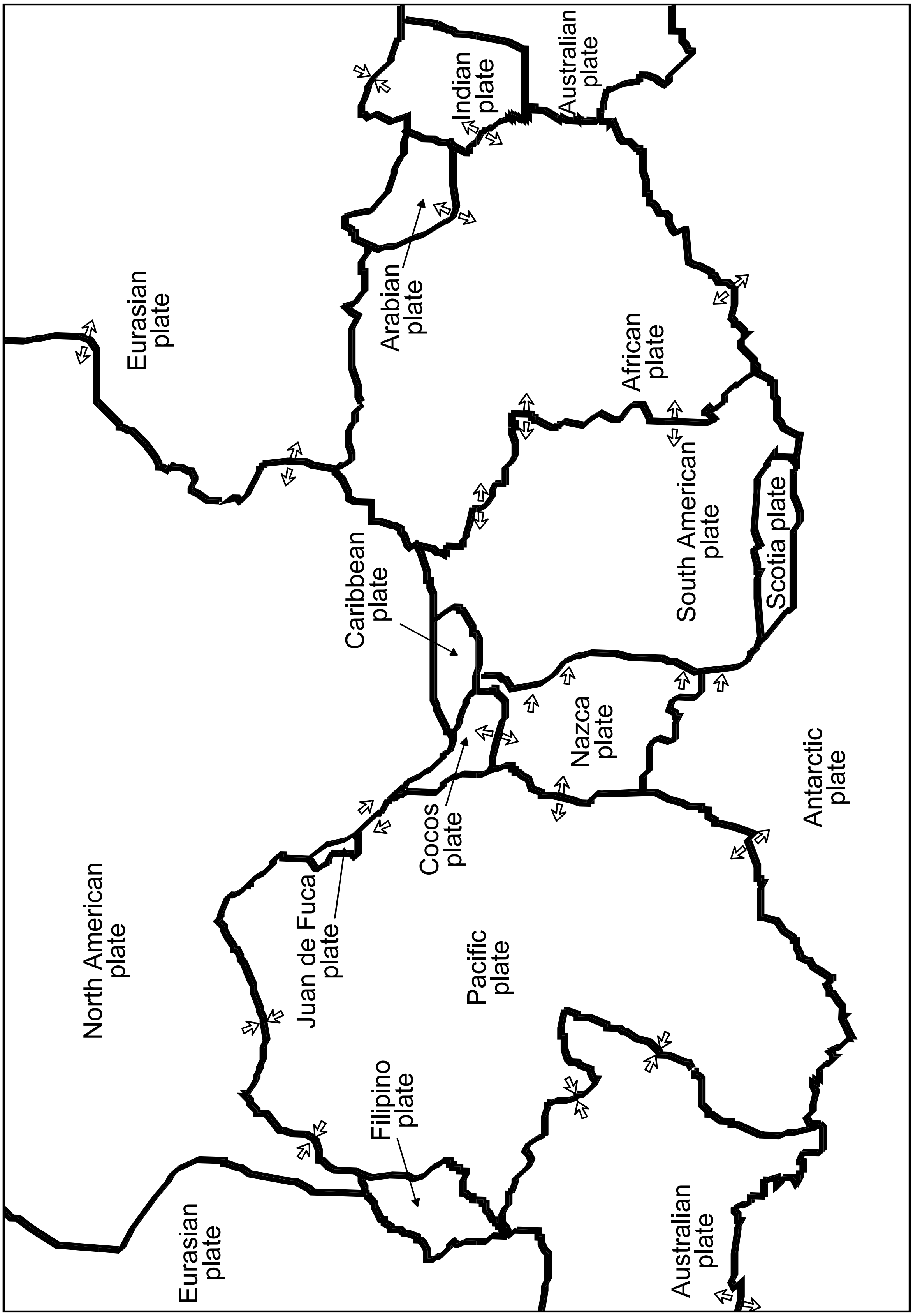
Indigenous perspectives

- Contact the local Indigenous Land Council or cultural heritage centre to make contact with local Indigenous community members. Consult with them about Indigenous understanding of earthquakes and other natural phenomena in your areas.
- Ask students to interview a local Indigenous community member or an Indigenous education officer about traditional knowledge of earthquakes. Students might like to present their interview as part of their 'seismologist' report in Lesson 7.

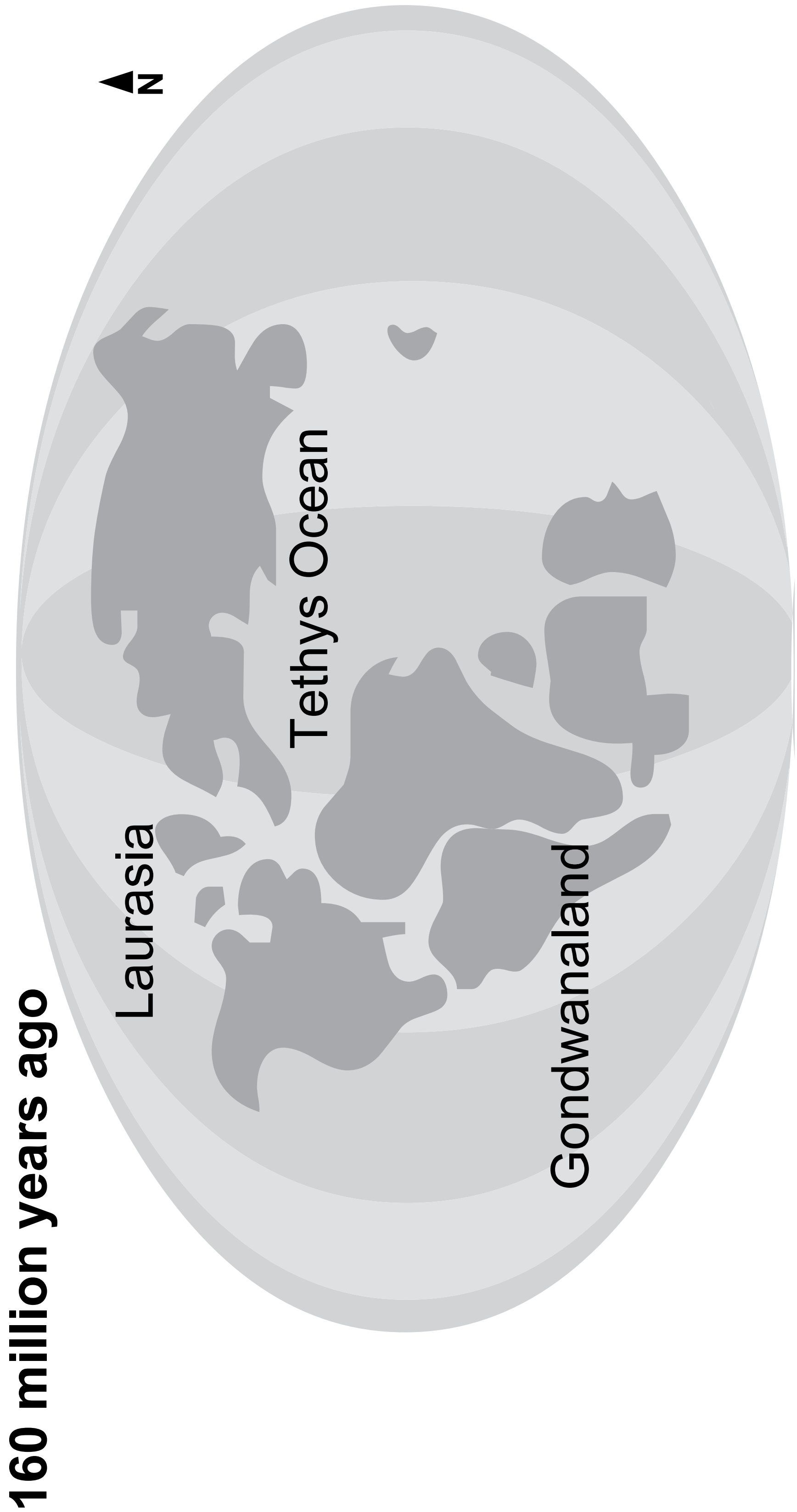
Map of the continents



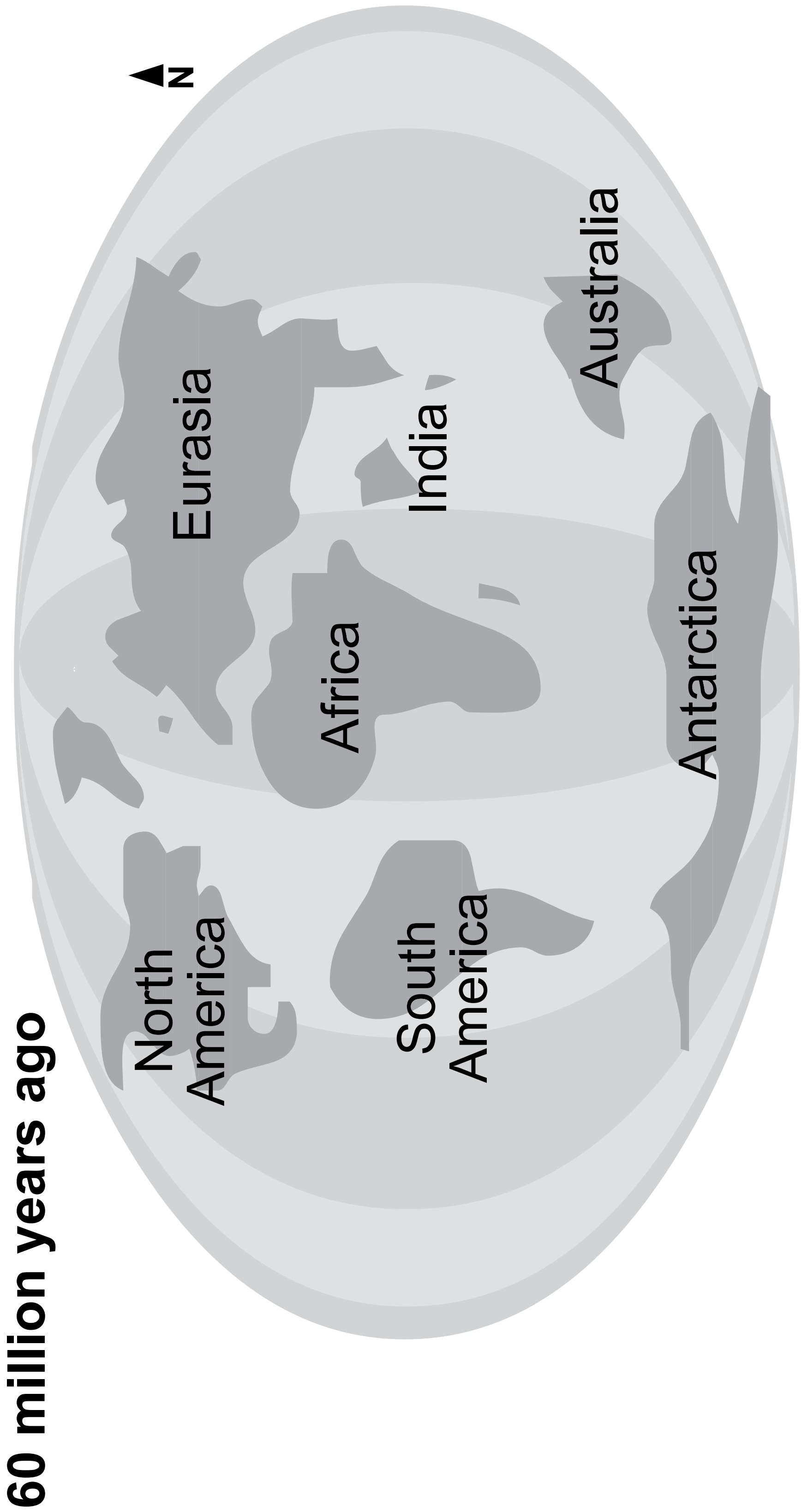
Map of the plate boundaries



Continent formation: 160 million years ago



Continent formation: 60 million years ago



Lesson 5 Earthquakes down under

AT A GLANCE

To support students to investigate and compare earthquake activity in Australia and neighbouring countries.

Students:

- review what they have learned about earthquakes
- compare and discuss data about the occurrence of earthquakes in Australia and neighbouring countries
- suggest reasons for the higher rate of occurrence of earthquake activity in some of Australia's neighbouring countries.

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 2). Rubrics will be available on the website to help you monitor students' inquiry skills.

ELABORATE

Key lesson outcomes

Science

Students will be able to:

- interpret evidence of and describe earthquake activity for Australia
- represent results as a graph
- compare and suggest reasons for the difference in earthquake magnitude and frequency between Australia and neighbouring countries.

Literacy

Students will be able to:

- read and analyse earthquake data
- collect and interpret earthquake information
- use a graph to record and represent findings
- contribute to a class discussion about the difference in earthquake activity between Australia and neighbouring countries.

This lesson also provides opportunities to monitor the development of students' general capabilities (highlighted through icons, see page 6).

Teacher background information

There are millions of earthquakes happening all around the world each year. Most of them release such a small amount of energy that we know they occur only because seismologists now have very sensitive recording instruments. Earthquakes can occur everywhere; low-magnitude earthquakes occur in Australia every year even though it is in the middle of a tectonic plate. One of the reasons why these intra-plate earthquakes occur is that pockets of weakness can respond to pressures exerted on the tectonic plate's edge.

Australia's neighbours, such as Indonesia and New Zealand, experience more high-magnitude earthquakes than Australia does. This is because they are situated on tectonic plate boundaries where the colliding tectonic plates meet, generating enormous pressure between them. When the pressure builds up, the tectonic plates move relative to each other and many high-magnitude seismic waves are generated. These cause violent shaking at the Earth's surface, increasing the chance of significant damage being caused.

Further information about the occurrence of earthquakes can be found on the Geoscience Australia website: www.ga.gov.au

Equipment

FOR THE CLASS

- class science journal
- word wall
- TWLH chart
- large map of Australia
- 1 overhead transparency of 'Map of the continents' (Resource sheet 7)
- coloured overhead markers
- 15 red self-adhesive dots
- 15 blue self-adhesive dots

FOR EACH STUDENT

- science journal
- 1 copy of 'Earthquakes around the world' (Resource sheet 11)
- 1 copy of 'Earthquake information: 1–15 December 2011' (Resource sheet 12)

Preparation

- Read 'How to facilitate evidence-based discussions (Appendix 5)
- Read 'How to construct and use a graph' (Appendix 6). Source a large map of Australia for classroom use.
- **Note**: Updated earthquake data can be found at the Geoscience Australia website. http://www.ga.gov.au/earthquakes/index.jsp
- *Optional:* Display the map of Australia and 'Map of the continents' (Resource sheet 7) on an interactive whiteboard or a computer connected to a projector. Check the Primary**Connections** website to see if an accompanying interactive resource has been developed: www.science.org.au/primaryconnections

Lesson steps

1 Review the previous lesson including the class science journal, glossary and the TWLH chart.

2 Introduce the ‘Map of the continents’ (Resource sheet 7) overhead transparency and invite students to use a coloured overhead marker to indicate where they think earthquakes might occur, particularly in areas around Australia and neighbouring countries including New Zealand, Papua New Guinea, Fiji and the Solomon Islands. Encourage students to provide reasons for their selection.

3 Ask students to predict how many earthquakes might happen in these areas every year. Discuss whether all of these earthquakes might cause severe damage. Encourage students to support their predictions with reasons.

4 Distribute a copy of ‘Earthquakes around the world’ (Resource sheet 11) to each student and read and discuss the factual text and earthquake data with the class. Ask questions such as:

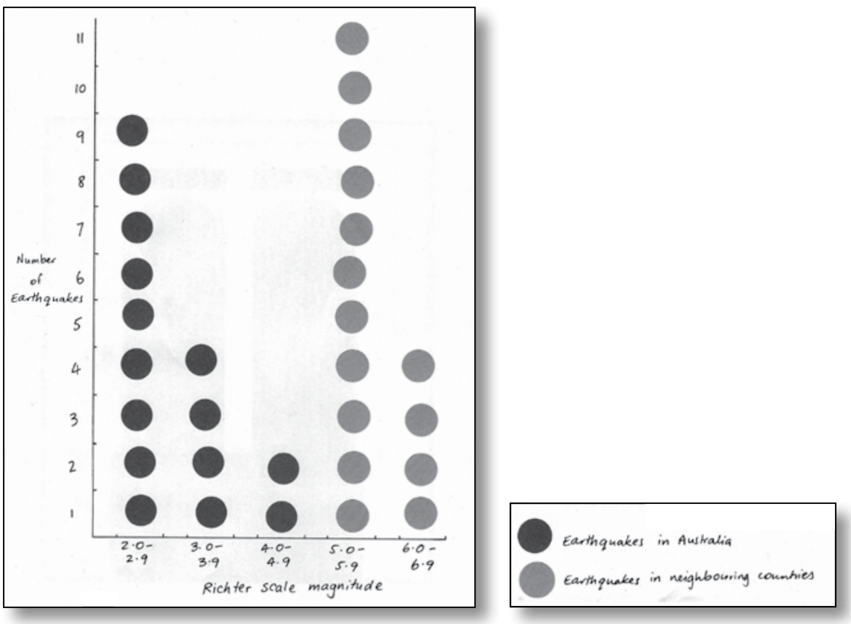
- How many earthquakes bigger than 9 on the Richter scale occur every year?
- How many earthquakes measuring between 6 and 9 on the Richter scale occur every year?
- How might a 7 or 8 Richter scale earthquake affect a city or other built-up area?
- How might the same size earthquake affect an uninhabited area, for example, a desert?

Encourage students to refer to the Richter scale and Modified Mercalli scale from Lesson 2.

5 Distribute a copy of ‘Earthquake information: 1-15 December 2011 (Resource sheet 12) to each student. Explain that the class will compare the frequency and magnitude of earthquakes in Australia and neighbouring countries by constructing a column graph. Discuss and record a suitable title for the graph. Discuss the purpose and features of a graph.

ELABORATE

Earthquake magnitude and frequency recorded in Australia and neighbouring countries



Class column graph

Literacy focus

Why do we use a graph?

We use a **graph** to organise information so we can look for patterns. We use different types of graphs, such as picture, column, or line graphs, for different purposes.

What does a graph include?

A **graph** includes a title, axes with labels on them and the units of measurement.

6 Allocate a student to each earthquake recorded on 'Earthquake information: 1–15 December 2011' (Resource sheet 12) and invite each student to place a self-adhesive dot on the column graph in the class science journal. Remind students to use red self-adhesive dots to represent Australian earthquake activity and blue self-adhesive dots to represent earthquake activity in neighbouring countries.

Note: Remind students that the number of self-adhesive dots is an indication of the number of earthquakes rather than an indication of earthquake magnitude.

7 Ask students to work in pairs to describe the patterns in the column graph. Ask pairs to discuss questions such as:

- What is the story of the column graph? What are the patterns?
- How would you describe the difference in earthquake activity between Australia and neighbouring countries?
- Where do stronger earthquakes occur? (Australia or neighbouring countries?)

8 Ask the class to use their understanding of tectonic plate movement to suggest reasons why some countries are more prone to intense and frequent earthquakes than Australia, such as New Zealand, Indonesia and Papua New Guinea. Ask questions such as:

- Why do stronger earthquakes occur near plate boundaries?
- Where would you choose to live if you wanted to be safe from strong earthquakes?
- What things might people who live in areas prone to strong earthquakes do to safeguard themselves and their surroundings against the effects of earthquakes?

9 Encourage students to question each other using the 'Science questions starters' in Appendix 5.

10 Ask students if they would like to reconsider their decision and move the coloured mark that they put on the 'Map of the continents' in Lesson step 2. Encourage students to provide reasons if they move their coloured mark or explain why they chose not to move their mark.

11 Update the TWLH chart, word wall and students' individual glossaries in their science journal.

Curriculum links

Science

- Research scientists who have been involved in the development of the Richter scale and Modified Mercalli scale.
- View a video about German geologist and meteorologist, Alfred Wegener, who first proposed the idea of tectonic plate movement.
  See: http://science.discovery.com/videos/100-greatest-discoveries-shorts-continental-drift.html

Mathematics

- Create graphs of earthquake activity in other countries.
- Calculate the mode, mean and median for earthquake data for Australia and neighbouring countries.

Information and communication technology

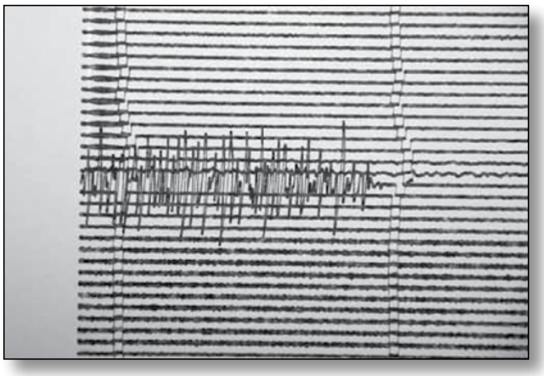
- Ask each team to create their column graph using digital technologies.

Earthquakes around the world

Name: ______________________________ **Date:** ______________

Scientists measure the magnitude of earthquakes using an instrument called a 'seismometer'. This instrument allows scientists to work out the size of an earthquake by recording ground movement and vibrations caused by the earthquake. These recordings are called 'seismograms'.

Seismometer



Seismogram

Images courtesy of Geoscience Australia

The magnitude of an earthquake is measured on a scale called the Richter scale, designed by Charles Richter in 1935.

A low value on the Richter scale means the surface of the Earth did not move very much.

A high value on the Richter scale means there was a great deal of movement.

Earthquakes recorded around the world

How big? (Richter scale)	How often? (approximately)
Bigger than 10	Never recorded
10	Very rare–Once every 20 years
9	1 every year
8	18 every year
7	120 every year
6	800 every year
5	6,200 every year
4	49,000 every year
3	365,000 every year
Less than 2 (microquakes)	2,920,000 every year

Source: http://en.wikipedia.org/wiki/Richter_scale (modified from US Geological Survey)

Earthquake information: 1–15 December 2011

Name: ______________________________ **Date:** ______________

Earthquake magnitude (Richter scale)	Australia
2	Australia (NSW)
2.1	Australia (NSW)
2.2	Australia (NSW)
2	Australia (SA)
2.4	Australia (SA)
1.7	Australia (SA)
2.4	Australia (SA)
1.9	Australia (NT)
5.1	Australia (WA)
1.9	Australia (SA)
1.7	Australia (SA)
2	Australia (VIC)
3.4	Australia (WA)
2	Australia (WA)
1.8	Australia (WA)

Earthquake magnitude (Richter scale)	Neighbouring countries
5.2	Indonesia
5.4	Indonesia
5.7	Indonesia
5.1	Indonesia
5	Indonesia
5.2	Indonesia
6.3	Indonesia
5.2	Indonesia
5.2	New Zealand
5	Papua New Guinea
7.2	Papua New Guinea
5.1	Santa Cruz Islands
5.2	Solomon Islands
5.3	Tonga Islands
5.2	Tonga Islands

Source: www.ga.gov.au/earthquakes

Lesson 6 So you want to be a seismologist?

AT A GLANCE

To support students to investigate and model how scientists collect information about earthquakes.

Students:

- review their understanding of how earthquakes are measured
- make a simple seismometer.

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 2). Rubrics will be available on the website to help you monitor students' inquiry skills.

Key lesson outcomes

Science

Students will be able to:

- review their understanding of the Richter and Modified Mercalli scales
- explain that seismologists use scientific instruments to observe, measure and record earthquake activity
- explain that a seismologist is a scientist who studies earthquakes.

Literacy

Students will be able to:

- use talk to describe the Richter and Modified Mercalli scales
- contribute to a class discussion about how scientists study and record information about earthquakes
- discuss and describe what the seismogram tells us about earthquake magnitude.

This lesson also provides opportunities to monitor the development of students' general capabilities (highlighted through icons, see page 6).

ELABORATE

Teacher background information

When movement of the Earth's surface occurs, waves of energy pass through the Earth. These waves are called seismic waves. Seismology is the scientific study of seismic waves (seismo, meaning 'earthquake'). It includes the study of seismic waves resulting from earthquakes, tsunamis, volcanic activity and landslides. It also includes the study of seismic waves caused by meteorite impact and human activity, for example, explosions and mine collapses. Scientists who work in seismology are called seismologists.

Seismologists use instruments called seismometers to record and measure these waves. A seismogram is a recording of movement of seismic waves through the Earth. Early seismometers were mechanical; modern seismometers are electronic and digital. Seismologists analyse seismograms to determine the magnitude of earthquakes and their point of origin.

There are thousands of seismometers networked and gathering data around the world. It is a complex process to analyse the information that is collected and to present it in a format that is useful for interpretation. Computers with high computational capacity are necessary for this task. Earthquake activity is monitored closely, and reports to government agencies are posted regularly and frequently on international websites and through government agencies. At this point in time, however, earthquakes cannot be predicted precisely.

Equipment

FOR THE CLASS

- class science journal
- word wall
- TWLH chart
- 1 small table
- 1 felt-tip pen
- 1 x 30 cm ruler
- 1 length of paper (see 'Preparation')

FOR EACH TEAM

- role wristbands or badges for Director, Manager and Speaker
- each team member's science journal
- 1 small table
- 1 felt-tip pen
- 1 x 30 cm ruler
- 3 lengths of paper (see 'Preparation')

ELABORATE

Preparation

- Cut and prepare three 30 cm x 100 cm lengths of paper for each team and one for the class.

Lesson steps

1 Review the previous lesson including the class science journal, glossary and the TWLH chart. Review and discuss how scientists measure earthquakes using a machine called a seismometer and use scales called the 'Richter scale' and the 'Modified Mercalli scale' (see 'Lesson 2') to describe the magnitude and intensity of earthquakes.

2 Explain that students will investigate how scientists study and record earthquake activity. Ask students what they think a scientist who investigates earthquakes is called. Introduce the term 'seismology'. Add the terms 'seismologist' and 'seismology' to the class word wall and the glossary recorded in the class science journal.

3 Explain that a key tool of the seismologist is the seismometer. Invite three students to demonstrate a simple model of a seismometer for the class.

- Ask one student to hold the pen and ruler in position.
- Ask the second student to gently pull the paper across the table steadily.
- Ask the third student to shake the table from side to side, gently at first, and then more strongly.

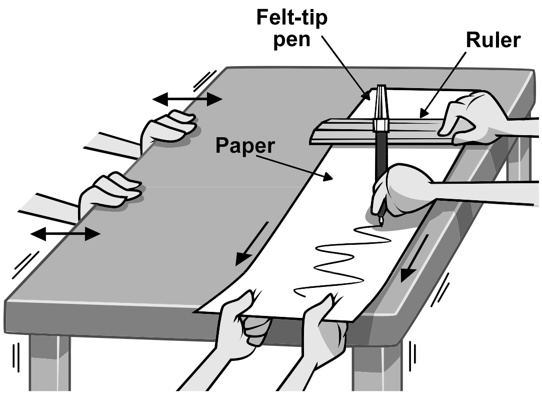


Illustration of the seismometer

Use the resulting seismogram to show the class how a gentle earthquake produces small waves and a strong earthquake produces larger waves.

4 Explain that students will be working in collaborative learning teams to make a model of a seismometer.

5 Form teams and allocate roles. Ask Managers to collect team equipment from the equipment table. Encourage each member of each team to have a turn at each role so that students have their own seismogram. Ask team members to glue their seismogram into their science journal and write a description of their seismogram, highlighting where weaker and stronger movement is recorded.

6 Ask teams to discuss refinements to the methods used, and how the quality of the data might be improved, as well as alternate methods and their suitability.

7 Ask each team to present their seismograms to another team and discuss patterns in the data, possible refinements in the methods used, and alternate methods.

8 Add any further information to the third column ('What we Learned') and fourth column ('How we know') of the TWLH chart. Update the word wall and students' individual glossaries in their science journal.

Curriculum links

Science

- Interview a seismologist or visit the Australian Academy of Science website for the 'Interview with Australian scientists' project. See: www.science.org.au/scientists/index.htm
- Research other uses of seismometers, for example, measuring explosions.

Mathematics

- Use appropriate units to measure and compare readings on seismograms created in Lesson step 5.

Lesson 7 On location

AT A GLANCE

To provide opportunities for students to represent what they know about how sudden geological changes or extreme weather conditions can affect Earth's surface and to reflect on their learning during the unit.

Students:

- present a 'seismologist' report from a recent earthquake
- 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:

- sudden geological changes such as earthquakes can affect Earth's surface, and how scientific understandings are used to develop explanations of events that directly affect people's lives and inform personal and community decisions.

Literacy products in this lesson provide useful work samples for assessment using the rubrics provided on the Primary**Connections** website.

Key lesson outcomes

Science

Students will be able to:

- explain that the Earth's surface is made of tectonic plates that move
- describe three types of plate movement
- discuss the causes and effects of earthquakes
- describe the scales that are used to measure the intensity and magnitude of earthquakes
- describe how seismologists measure and record earthquake activity.

Literacy

Students will be able to:

- use talk to present a 'seismologist' report to an audience
- use oral, written and visual forms to present their understanding of earthquakes
- reflect on their learning in a science journal entry.

This lesson also provides opportunities to monitor the development of students' general capabilities (highlighted through icons, see page 6).

Equipment

FOR THE CLASS

- class science journal
- word wall
- TWLH chart
- 1 enlarged copy of 'Earthquake presentation planner' (Resource sheet 13)
- 1 enlarged copy of 'Quality matrix and Radar chart' (Resource sheet 14)
- coloured markers

FOR EACH STUDENT

- science journal
- 1 copy of 'Earthquake presentation planner' (Resource sheet 13)
- 1 copy of 'Quality matrix and Radar chart' (Resource sheet 14)

EVALUATE

Preparation

- Prepare an enlarged copy of 'Earthquake presentation planner' (Resource sheet 13) and 'Quality matrix and Radar chart' (Resource sheet 14).

Lesson steps

1. Review the previous lesson including the class science journal, glossary and TWLH chart.
2. As a class, review and discuss each column of the TWLH chart, adding students' responses to the fourth column ('How we know'). Ask students questions such as:
   - What did we know about earthquakes at the beginning of the unit?
   - What questions did we have about earthquakes?

- What have we learned about earthquakes?
- What evidence do we have for how we know?

3 Ask students if they can recall the title of a scientist who studies earthquakes. Review the machine and the scales used to measure and record earthquakes and discuss how seismologists use this recorded information.

4 Explain that students are going to become seismologists and will plan a presentation about an earthquake. Discuss information that might be useful to include in the presentation.

5 Introduce an enlarged copy of 'Earthquake presentation planner' (Resource sheet 13) and discuss each section. Explain that students will use the 'Earthquake presentation planner' to collect and record information about an earthquake and will present this information to the class.

6 Discuss how students can present their information, for example, oral report, interactive whiteboard presentation or poster. Encourage students to use different types of visual representations supported by oral and written representations.

7 Introduce an enlarged copy of the 'Quality matrix and Radar chart' (Resource sheet 14). Explain to students that the 'Quality matrix' will assist them in addressing the criteria of a high-quality presentation and allow each student to participate in self-assessment. Ask students questions such as:

- What features should each presentation include? (Such as, information about earthquakes, clear presentation style, oral and visual information.)
- What would it look like or sound like if done well? (Such as, clear voice, effective use of materials, confident speaker.)

8 Record students' responses in the first and second columns of the 'Quality matrix'. Ask students to collect a copy of the 'Quality matrix', record the responses on their copy and paste it into their science journal.

9 Allow time for students to prepare and practise their presentations. Invite each student to present their information.

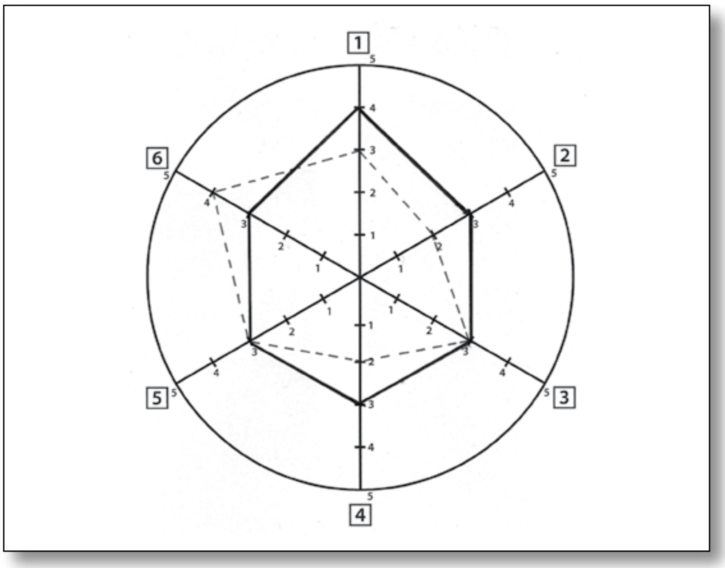
Note: This end-of-unit presentation may need several sessions to complete.

10 After students have presented their end-of-unit presentation, ask students to use their copy of the 'Radar chart' to rate themselves between 1 and 5 (1 = least effective to 5 = most effective) for how well they exhibited each characteristic during their presentation.

11 Discuss with each student their 'Quality matrix' and 'Radar chart' and provide feedback on each student's presentation. Use a different coloured marker (or line) to rate each student's presentation, using the same 1–5 scale on the student's 'Radar chart'.

Optional: Use peer assessment to evaluate presentations.

EVALUATE



Radar chart sample

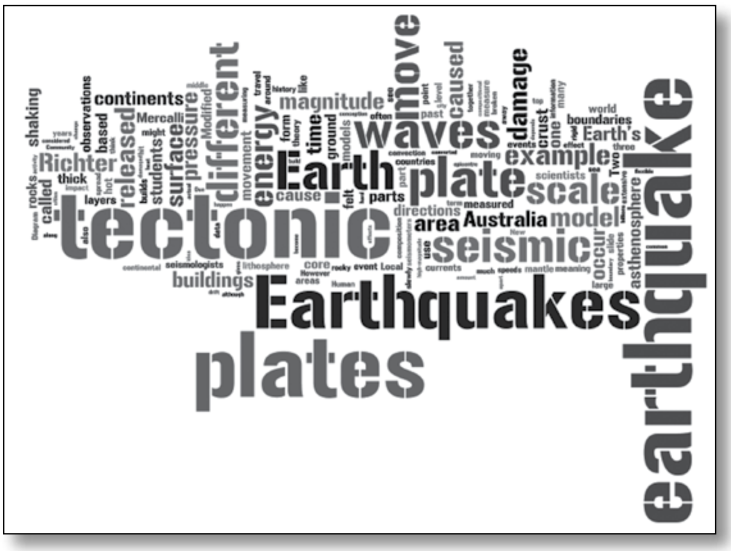
12 Invite each student to use their radar chart to reflect on how they can improve their presentation and ask them to complete the third column of their 'Quality matrix', focusing on one or two features they could improve.

13 Review the Earthquake explorers unit with the class, asking questions such as:

- What were the most interesting things that you have learned?
- How well do you feel you have learned about earthquakes?
- What helped you to learn?
- What are you still wondering about?
- What are the advantages and disadvantages of working in a team?

Record students' responses in the class science journal.

Optional: Ask students to use Wordle to create a word cloud for their earthquake presentation.



***Earthquake explorer's* word cloud**

Wordle generates 'word clouds' from given text. See http://wordle.net/

Earthquake presentation planner

Name: ____________________ **Date:** ____________________

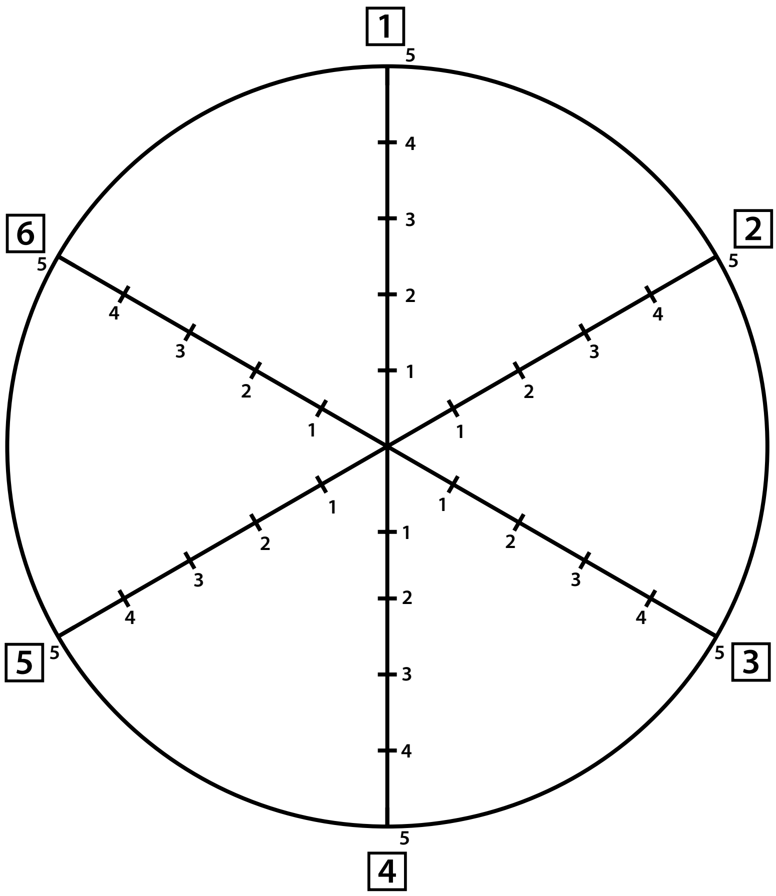
What happened?	**Where did it happen?**	**When did it happen?**
What was the Richter scale reading?	**What was the Modified Mercalli scale level?**	**Who was affected?**
Describe the damage caused.	**What could have caused the earthquake?**	

Quality matrix

Name: ______________________________ **Date:** ________________

Features	What would it look like or sound like if it was done well?	How can I improve on this feature?
1.		
2.		
3.		
4.		
5.		
6.		

Radar chart



Appendix 1
How to organise collaborative learning teams (Year 3–Year 6)

Introduction

Students working in collaborative teams is a key feature of the Primary**Connections** 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 multi-modal 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 7.

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 learn to work 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, the 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, for example 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

Primary**Connections** 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 SKILLS

1 Move into your teams quickly and quietly

2 Speak softly

3 Stay with your team

4 Take turns

5 Perform your role

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

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, 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 2 and 7.

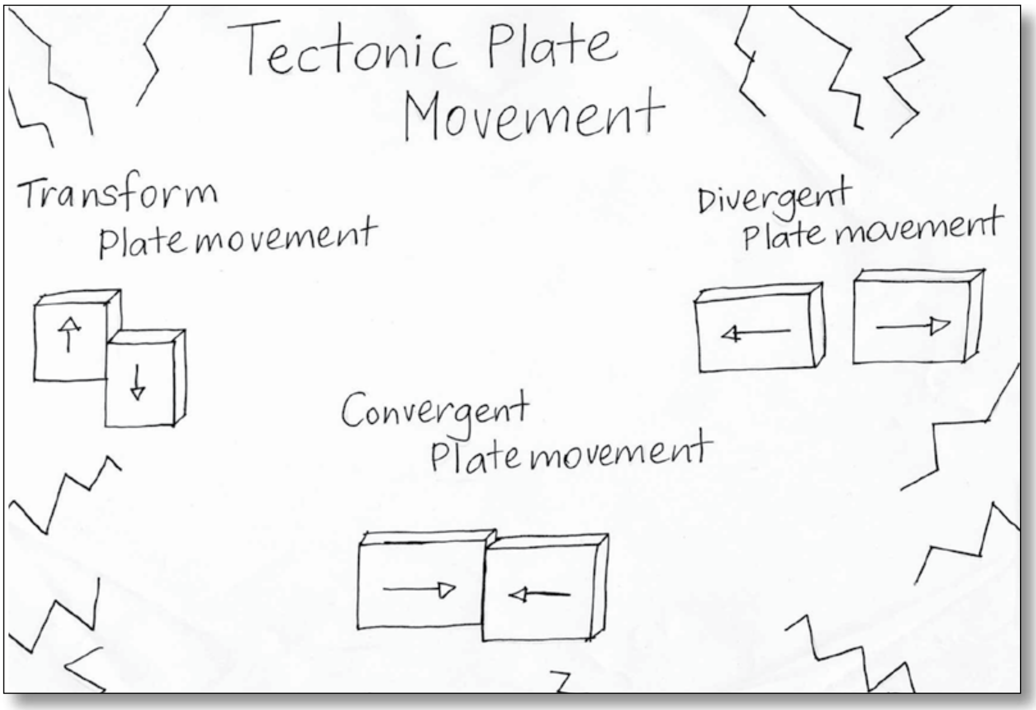
Using a science journal

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 class. 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-taking, 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.



***Earthquake explorers* science journal**

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 regional dialects and languages, aligns to descriptions in the Australian Curriculum: English. See page 7.

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-fastening 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 *Earthquake explorers* unit might be organised using headings, such as ‘Tectonic plates’, ‘earthquake magnitude’ and ‘Seismologists’.

Sounds sensational **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 individually during literacy experiences. Organise multi-level activities to cater for the individual needs of students.

Earthquake explorers **word wall**

Appendix 4
How to use a TWLH chart

Introduction

A learning tool commonly used in classrooms is the KWL chart. It is used to elicit students' prior **K**nowledge, determine questions students **W**ant to know answers to, and document what has been **L**earned.

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

T—'What we **think** we know' is used to elicit students' background knowledge and document existing understanding and beliefs. It acknowledges that what we 'know' might not be the currently accepted scientific understanding.

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

L—'What we **learned**' is introduced as students develop explanations for their observations. These become documented as 'claims'.

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.

***Earthquake explorers* 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)
We think that earthquakes happen in Japan and America.	Can earthquakes happen in Australia?	Earthquakes can happen in Australia, but most are of a low magnitude. Most high magnitude earthquakes occur near tectonic plate boundaries.	We analysed the earthquake data from different regions of the world. We used models of the tectonic plates to investigate how earthquakes form at their boundaries.

Appendix 5
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 other's 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. Such as:

- 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, 'Where do stronger earthquakes occur?'

C—The **claim**, for example, 'Stronger earthquakes occur at plate boundaries rather than in the middle of plates.'

E—The **evidence**, for example, 'The earthquake data showed that countries such as Papua New Guinea, Indonesia, and New Zealand which lie near plate boundaries have experienced stronger earthquakes than Australia'.

R—The **reasoning**—saying how the evidence supports the claim, for example, 'Australia, which lies in the middle of a tectonic plate experiences weaker earthquakes. Tectonic plates move past each other and build up stress at the boundaries. This stress is sometimes released in the form of earthquakes'.

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 Primary**Connections** 5Es DVD, Chapter 5).

Science question starters

Question type	Question starter
Asking for evidence	I have a question about ____________________ . How does your evidence support your claim? What other evidence do you have 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 ____________________? What do you think will happen if ____________________?
Clarifying	I'm not sure what you meant there. Could you explain your thinking to me again?

Appendix 6
How to construct and use a graph

Introduction

A graph organises, represents and summarises information so that patterns and relationships can be identified. Understanding the conventions of constructing and using graphs is an important aspect of scientific literacy.

During a scientific investigation, observations and measurements are made and measurements are usually recorded in a table. Graphs can be used to organise the data to identify patterns, which help answer the research question and communicate findings from the investigation.

The Australian Curriculum: Mathematics Statistics and Probability 'Data representation and interpretation' content descriptions for Year 6 are:

- Interpret and compare a range of data displays, including side-by-side column graphs for two categorical variables.
- Interpret secondary data presented in digital media and elsewhere.

Once you have decided to construct a graph, two decisions need to be made:

- What type of graph? and
- Which variable goes on each axis of the graph?

What type of graph?

The type of graph used depends on the type of data to be represented. Many investigations explore the effect of changing one variable while another is measured or observed.

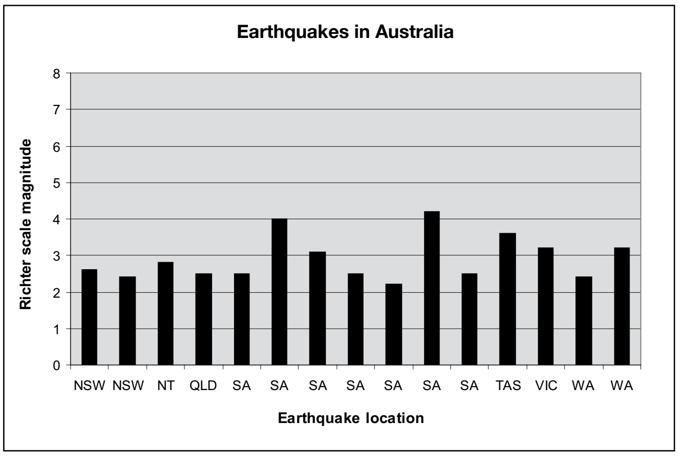
Column graph

Where data for one of the variables are in **categories** (that is, we use **words** to describe it, for example, earthquake location) a **column graph** is used. In *Earthquake explorers*, students analyse and compare secondary data. Students use their understanding of earthquakes to explain the patterns in the data. Graph A below shows the magnitude of earthquakes in Australian states and territories **(data in categories)** and is presented as a **column graph**.

Table A: Earthquake magnitude recorded in Australian states and territories from October 2008 to November 2008.

Earthquake magnitude (Richter scale)	Australia
2.6	Australia (NSW)
2.4	Australia (NSW)
2.8	Australia (NT)
2.5	Australia (QLD)
2.5	Australia (SA)
4.0	Australia (SA)
3.1	Australia (SA)
2.5	Australia (SA)
2.2	Australia (SA)
4.2	Australia (SA)
2.5	Australia (SA)
3.6	Australia (TAS)
3.2	Australia (VIC)
2.4	Australia (WA)
3.2	Australia (WA)

Graph A: Earthquake magnitude recorded in Australian states and territories from October 2008 to November 2008.



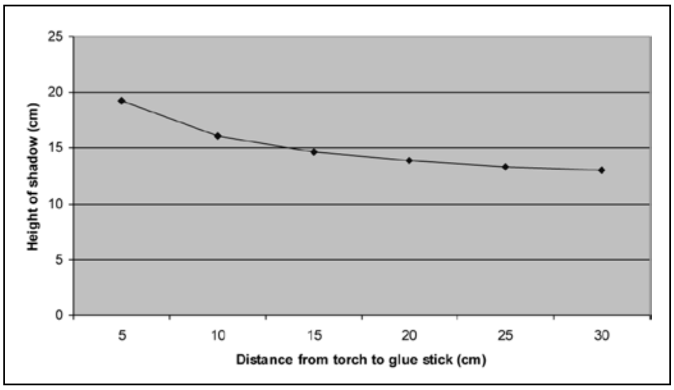
Line graph

Where the data for both variables are **continuous** (that is, we use **numbers** that can be recorded on a measurement scale, such as length in centimetres or mass in grams), a **line graph** is usually constructed. Graph B below shows how the results from an investigation of the effect of distance from a light source **(continuous data)** on the shadow height of an object **(continuous data)** have been constructed as a **line graph**.

Table B: The effect of distance from a torch on the shadow height of a glue stick.

Distance from torch to glue stick (cm)	Height of shadow (cm)
5	19.3
10	16.1
15	14.7
20	13.9
25	13.3
30	13

Graph B: The effect of distance from a torch on the shadow height of a glue stick.



Which variable goes on each axis?

It is conventional in science to plot the variable that has been changed on the horizontal axis (X axis) and the variable that has been measured/observed on the vertical axis (Y axis) of the graph.

Graph titles and labels

Graphs have titles and each variable is labelled on the graph axes, including the units of measurement. The title of the graph is usually in the form of 'The effect of one variable on the other variable'. For example, 'The effect of distance from a torch on the shadow height of a glue stick' (Graph B).

Steps in analysing and interpreting data

Step 1—Organise the data (for example, construct a graph) so you can see the pattern in data or the relationship between data for the variables (things that we change, measure/observe, or keep the same).

Step 2—Identify and describe the pattern or relationship in the data.

Step 3—Explain the pattern or relationship using science concepts.

Questioning for analysis

Teachers use effective questioning to assist students to develop skills in interrogating and analysing data represented in graphs. Such as:

- What is the story of your graph?
- Do the data in your graph reveal any patterns?
- Is this what you expected? Why?
- Can you explain the pattern? Why did this happen?
- What do you think the pattern would be if you continued the line of the graph?
- How certain are you of your results?

Analysis

Analysis of Graph B shows that the further the distance from the torch the shorter the height of the glue stick's shadow. This is because as light travels in straight lines, the closer the object to a light source, the more light it blocks out and therefore the bigger the shadow.

Appendix 7
Earthquake explorers **equipment list**

EQUIPMENT ITEM	QUANTITIES	LESSON	1	2	3	3	4	4	5	6	7
		SESSION			1	2	1	2			
Equipment and materials											
cardboard, several small pieces, 7 cm x 4 cm approximately	several per team						•				
egg, hard-boiled	1 per team				•	•					
envelope	1 per team			•							
knife	1 per team					•					
magnifying glass optional	1 per class				•						
map of Australia, large	1 per team								•		
markers, coloured overhead	1 per class							•	•		•
paper, 30 cm x 100 cm	1 per class and 3 per team									•	
pen, felt-tipped	1 per class and 1 per team									•	
plasticine											
– 3 sets of 2 pieces, 20cm x 10cm each	3 sets per class				•						
– 10 cm x 10 cm pieces	2 per student						•				
roll of toilet paper	1 per class							•			
ruler, 30 cm	1 per class and 1 per team									•	
self-adhesive dots											
– blue	15 per class								•		
– red	15 per class								•		
self-adhesive notes	5 per class							•			
table, small	1 per class and 1 per team									•	
toothpicks	several per team						•				

* These lesson outcomes are aligned to relevant descriptions of the Australian Curriculum. See page 2 for Science and page 7 for English and Mathematics.

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Linking science with literacy

Australian Academy of Science

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PrimaryConnections: linking science with literacy is an innovative program linking the teaching of science with the teaching of literacy in primary schools. The program includes a professional learning component and curriculum units aligned to the Australian Curriculum: Science.

Research has shown that the professional learning component of the Primary**Connections** program significantly enhances the implementation of the curriculum units. Professional Learning Facilitators are available throughout Australia to conduct a variety of workshops. At the heart of the professional learning program is the Curriculum Leader Training Program.

Primary**Connections Curriculum Leader Training Program**

Held annually, this two-day workshop develops a comprehensive understanding of the Primary**Connections** program. Participants receive professional learning resources that can be used to train others in Primary**Connections**.

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The professional learning calendar, other workshops and booking forms can be found on the website: www.science.org.au/primaryconnections

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<table>
<tr><th>Year</th><th>Biological sciences</th><th>Chemical sciences</th><th>Earth and space sciences</th><th>Physical sciences</th></tr>
<tr><td>F</td><td>Staying alive</td><td>What's it made of?</td><td>Weather in my world</td><td>On the move</td></tr>
<tr><td>1</td><td>Schoolyard safari</td><td>Spot the difference</td><td>Up, down and all around</td><td>Look! Listen!</td></tr>
<tr><td>2</td><td>Watch it grow!</td><td>All mixed up</td><td>Water works</td><td>Push pull</td></tr>
<tr><td>3</td><td>Feathers, fur or leaves?</td><td>Melting moments</td><td>Night and day</td><td>Heating up</td></tr>
<tr><td rowspan="2">4</td><td>Plants in action</td><td>Material world</td><td rowspan="2">Beneath our feet</td><td rowspan="2">Smooth moves</td></tr>
<tr><td>Friends and foes</td><td>Package it better</td></tr>
<tr><td>5</td><td>Desert survivors</td><td>What's the matter?</td><td>Earth's place in space</td><td>Light shows</td></tr>
<tr><td rowspan="2">6</td><td rowspan="2">Marvellous micro-organisms</td><td rowspan="2">Change detectives</td><td rowspan="2">Earthquake explorers</td><td>It's electrifying</td></tr>
<tr><td>Essential energy</td></tr>
</table>

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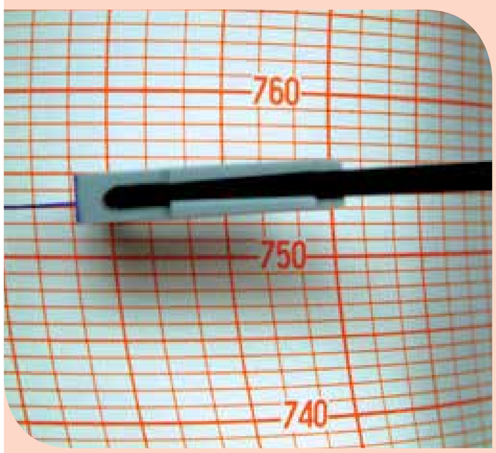

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