Best practice in Science teaching

Disposition to learn

To give your students a firm foundation of factual scientific knowledge, you need to teach some subject matter in depth, providing many examples in which the same concept is at work.

As a primary teacher, you need to have the core science knowledge and understand the concepts at least at the level you are teaching, regardless of your own scientific background and experience.

If you have created an environment in which the students are interested and are comfortable to wonder and ask questions, it is important that you value their questions and help them extend their ideas. When a question is asked, this is a crucial teachable moment, when you can model one of the key habits of scientific literacy—a disposition to learn. For example, 'I don't know why dead bodies float. What might be some reasons? How can we find out?'

Provoke curiosity

Inquiry is about questions, but it is hard for children to ask questions about something if they haven't had a chance to engage with it, whether it is balls rolling, snails or volcanoes. We need to intentionally provoke their curiosity, but not provide too much comment or direction. We can scaffold ways to gather students' responses and subsequent questions, but our learning intention is to engage and motivate them to want to learn about forces, gases and plants, for example, not to just answer their questions

- Let them play. Ask students to make predictions before trying. Focus the discussion with questions.
  - Before a discussion on the properties of materials or reversible and irreversible changes, display materials such as paint, glue, sand and water. Do not give any directions. Many examples and questions will follow their exploration.
  - Provide screwdrivers and allow students to disassemble electrical items (not plugged in and with cords cut). Ask the students to consider what energy transformations these items enable.
  - Suspend a magnet so it is hanging freely at a height. Each day, invite one or two students to make the magnet move without touching it.
  - Wrap up several boxes containing objects. Have students spend the week guessing what is in the boxes. Ask them what information their different senses gave them and to decide which sense was most helpful.
- Let students ponder a contradictory or startling statement related to the topic, such as:
  - Astronauts cannot belch. (There is no gravity to separate liquid from gas in their stomachs.)
  - Giraffes often sleep for only 20 minutes in any 24 hours. They may sleep up to 2 hours (in spurts—not all at once), but this is rare. They never lie down.

Students are intrigued by optical illusions.

- Optical illusions intrigue students. Can you see both an old and a young woman?
- Tell students you are going to show them a magic trick, and then just turn the classroom lights on or off. Give them a variety of materials—wires, batteries, small globes, pieces of plastic, pieces of metal—and ask students to prove that turning the lights on or off was not magic.

- Find videos, images and games on the internet. For forces or energy transfer, you could use videos of snooker players knocking down dominoes or a famous television advertisement for Honda called 'The Cog'.
- Use books, artwork and DVDs to stimulate interest.
  - The tale *Jack and the Beanstalk* can lead to an investigation of the ideal conditions for plant growth.
  - The poem *Jabberwocky* by Lewis Carroll can be used as a stimulus for the study of interdependence and adaptation. See Chapter 5 for further explanation.
  - *Tiger in a Tropical Storm* was painted by Henri Rousseau in 1891. It shows a tiger, illuminated by a flash of lightning, preparing to pounce on its prey. What adaptations help the tiger catch its prey? What adaptations might help the prey survive to live another day?
  - Any of the fiction or non-fiction *Discovering Science* titles can also be used to stimulate discussion of a science topic.

There are many more ways to stimulate students' interest in a science topic, including demonstrations, role-plays and displays. Mix it up—no single method suits every student. Step outside your comfort zone to keep students guessing and looking forward to your Science lessons.

Connect to real life

- How important is science?
- Does science matter?

What would you hope your students would say if you asked them these questions? An interesting activity is to make a storyboard of the students' day and then imagine how it would be without the impact of science. There would be no electricity, no mobile phones, no clean running water, no antibiotics for their sore throat, no car or train to transport them to school, no plastic … the list is endless.

A learning environment extending beyond the classroom walls is very important in science.

- Explore the school ground and local neighbourhood for possibilities. You could choose skateboards and playground equipment to study forces.
- Connect with the broader community.
  - Study the local environment, survey the local community and visit local industry.
  - Access expertise in parents and the general school community to provide input or support in a topic.
  - Access national, international and scientific communities through the internet as real or virtual guest speakers.
- Always look out for current newspaper and magazine articles and current affairs TV programs. A bulletin board or blog is ideal for displaying current news items relevant to the topic. Students can manage these once you get them started.

As you plan each sequence of learning, make sure you consider:

- how you can make this content and these concepts relevant to your students
- when your students would apply this knowledge and these skills.

Elicit prior knowledge and confront preconceptions

It is very important to find out what students already know about an area of science.

- Eliciting prior knowledge enables effective planning.
- It allows students to feel that what they already know and can do is useful and valued.
- You can uncover preconceptions. If students' ideas are to be changed, they need to have new experiences that challenge their prior knowledge.

We can't just present alternative knowledge; students will not let go of their own ideas of how the universe works unless they are introduced to different ideas that are more appealing. We need to know what students' preconceptions are in order to provide ways for students to compare their ideas with what they are learning in their Science lessons and to then clarify and explore their own thinking in a non-threatening environment. Encourage students to ask questions, talk together, speculate, make suggestions, argue and express opinions and alternative points of view.

- Bring along an animated toy. What can it do? Is it alive? Seek evidence to prove the students' responses.

- Write statements or questions on pieces of paper and place them around the classroom. Examples are 'Extinct volcanoes will never erupt' and 'No one should live near an active volcano'. Invite the students to make graffiti comments on these pieces of paper.
- Place the words *Agree* and *Disagree* on opposite walls. Read out statements and ask students to stand somewhere between the two words, depending on their responses to the statements. Ask students for their reasons for standing where they are.
- Invite students to put on different clothes made of different materials and in different amounts (for example, three jumpers). When do they feel warmer? Why? Is it the clothes or the heat from their body?

Many of the picture cards that accompany this book are ideal stimuli to invoke such discussions.

Challenge students to think

Challenging students to think is not specific to developing scientific literacy. However, the hands-on nature of good Science teaching provides many opportunities for encouraging students to think more deeply about ideas and concepts.

You can entice students to think by the way you respond to their questions.

- Do not readily provide information—avoid answering their questions directly or providing the knowledge you have on the topic. Pretend you don't know the answer!
- Ask students a question in response to their question to seek more information about the beliefs that lie beneath what they are asking and about what they may already know.
- Seek ideas from other students when questions are directed at you.
- Refocus students on what the question is asking. Ask the question in another way.
- Suggest a way the students can check the answer for themselves.

A framework such as Bloom's Taxonomy can be used to plan key questions so you are requiring students to move to higher-level thinking. As teachers, we tend to ask questions in the 'knowledge' category 80–90% of the time.

Wait between 3 and 10 seconds after you have asked a question and before a response is expected—this allows thinking time for both students and teachers. Ideally, this approach also includes thinking time for students after their response and before you or other students comment or respond to their answer. Research has shown that the use of such waiting or thinking time increases the quality and length of the students' responses and improves the variety and quality of teacher's questions as well as their willingness to listen to diverse answers. It takes practice on the part of both the teachers and students.

Give and expect thoughtful questions

It is important to value thoughtful questions from your students and model this yourself. Practice, exposure and specific teaching are key to developing a student's ability to ask thoughtful questions. Some suggested approaches useful in Science teaching follow.

- Use a question matrix such as the one on page 14. Students develop a set of questions using this matrix after viewing a photograph or video. Alternatively, make two dice with these words and roll them to provide the start of a student's question.

	Can	Would	Might	Does	Is	Could	Are
Why							
When							
How							
What							
Where							
Which							
Who							

- Ask students individually or in groups to brainstorm as many questions as they can from a stimulus or provocation. Collect a master list of these questions and use this to build an understanding of higher-order thinking questions. You could classify each question as a 'thinking' versus 'fact' or a 'clarifying' versus 'probing' question.
- Offer a fact, opinion, quote, statistic or piece of information as the possible answer to a question. What are the questions that could give rise to this as the answer?
- Have students record questions at the start and/or during a lesson sequence; display these. At the end of a lesson ask 'Which questions have been answered today?' The student who identifies a question is encouraged to explain how it was answered or what the answer to the question is. The original author of the question could decide if it has been fully answered and so it can be removed. Alternatively, use a question from the display as a focus for an activity or task, making sure you announce whose question you are answering.

An inquiry approach to planning

> The best, indeed the only preparation [for learning] is arousal to a perception of something that needs explanation, something unexpected, puzzling, peculiar.
> When the feeling of a genuine perplexity lays hold of any mind (no matter how the feeling arises), that mind is alert and inquiring.
>
> (John Dewey, *How We Think*, 1910)

The 5E model provides a framework for planning and implementing entire programs, specific units and individual lessons in Science. The 5Es represent the five phases of a sequence for teaching and learning: engage, explore, explain, elaborate and evaluate. The 5E model was developed by The Biological Science Curriculum Study (BSCS).

The following table describes the purpose of each phase as well as suggesting what the teacher and the student could be doing. It can be used as a prompt when planning.

Phase and purpose	Example actions to plan for:
Engage The purpose is to: • elicit prior knowledge • promote curiosity and engagement in a new concept or topic • make connections with what students already know and can do • ascertain students' questions about and areas of interest in this topic or concept.	What the teacher could be doing: • Uncovering what the students already know or think about the topic or concept by using an approach such as brainstorming, bundling, mind mapping or 'Finish the sentence' • Provoking curiosity and engagement by reading a vignette, posing questions, performing a demonstration, showing a video clip, using mystery boxes • Learning students' areas of interest using a KWL, paired interviews or a shared personal experience approach such as 'show and tell' or personal 'mystery bags' • Asking many questions and answering very few from students
	What the student could be doing: • Showing interest and curiosity by asking questions such as 'Why did this happen?', 'What do I already know about this?' and 'What can I find out about this?' • Sharing personal experiences
Explore The purpose is to: • challenge and use prior knowledge and beliefs to generate ideas • explore questions and possibilities • design and conduct a preliminary inquiry • provide a shared experience to process and reflect upon.	What the teacher could be doing: • Providing experiences that help students clarify their own understanding of major concepts and skills • Observing and listening to students as they interact • Asking questions to direct students' thinking and actions as they work together and investigate • Providing time for students to puzzle through problems
	What the student could be doing: • Working in collaborative teams • Exploring ideas through hands-on activities • Practising skills • Designing, planning and building models • Investigating to test predictions and form new predictions • Recording observations and ideas, collecting data • Asking questions and reflecting
Explain The purpose is to: • clarify students' understanding • introduce information related to the concept • challenge students' understanding.	What the teacher could be doing: • Clarifying students' explanations by asking for justification and evidence • Introducing related information such as formal terms and definitions, and explanations for concepts, processes, skills or behaviours • Using students' previous experiences as the basis for explaining concepts
	What the student could be doing: • Engaging in opportunities to explain their current understanding of the main concept and processes they are learning • Demonstrating new skills or behaviours • Explaining information in their own words • Listening to others and asking questions • Using recorded observations in explanations • Assessing their own understanding • Seeking to comprehend teacher explanations

Phase and purpose	Example actions to plan for:
Elaborate The purpose is to: • extend, challenge and broaden students' understanding • cater for personal interest.	What the teacher could be doing: • Revisiting an earlier activity, project or idea and building on it • Conducting an activity that requires students to apply explanations and skills to new, but similar, situations • Providing opportunities to practice and reinforce skills • Providing opportunities for students to investigate further • Providing alternative explanations to provoke thinking
	What the student could be doing: • Practising and refining skills • Developing deeper and broader understandings • Investigating areas of interest • Applying knowledge and skills in new situations • Designing and conducting their own investigations related to this concept or understanding
Evaluate The purpose is to: • assess and demonstrate students' progress towards planned outcomes • encourage students to reflect.	What the teacher could be doing: • Evaluating, through self-assessment, peer assessment and formal assessment, students' understanding and skills to augment formative (ongoing) assessments conducted during other phases • Providing opportunities for students to demonstrate an understanding of concepts and skills • Observing students to look for evidence of new or deeper learning as they apply new knowledge and skills • Providing opportunities for students to act on new beliefs (such as planting native plants at school, setting a personal goal to waste less water)
	What the student could be doing: • Demonstrating their knowledge and skills • Evaluating their own progress • Supporting their peers to evaluate their progress • Asking questions that would enable further investigations • Acting on their new learning if applicable, such as modifying their own behaviour

Science concepts

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The core scientific concepts in the Australian Curriculum: Science support the sequential development of knowledge and skills across and within the primary and secondary years for all three strands of Science Understanding, Science Inquiry Skills and Science as a Human Endeavour. The six concepts are:

- patterns, order and organisation
- form and function
- stability and change
- systems
- scale and measurement
- matter and energy.

Teaching scientific concepts

Teaching Science requires an explicit understanding of the key science concepts that the students are learning. In developing student learning, these concepts need to be seen as overarching ideas that are clearly interrelated. One topic or unit of work should provide opportunities to develop many if not all of these concepts for students. An important role of the teacher is to focus students' attention on these concepts through questioning, probing, well-planned activities and reflection. For example, students' fascination with volcanic eruptions could be used to focus on the location of volcanoes on a global scale (pattern and organisation), the structure of volcanic rocks and their uses (form and function) and students' comparative understanding of the terms *extinct* and *dormant* (stability and change).

Being very aware of the scientific concepts to be developed will help to direct your planning and guide your teaching decisions during classes. This will ensure that you do not miss opportunities to teach these concepts.

Patterns, order and organisation

Everywhere you look in the natural world, you can find patterns—from the pattern of weather to the migration of birds and our unique fingerprint patterns.

Scientists look for and study these patterns to give order to and to organise our understanding of the world around us. DNA patterns support medical diagnosis, the arrangement of particles in a solid help to explain its properties, and patterns of whale beaching inform predictions of future such events.

As students' progress from Foundation to Year 10 in the Australian Curriculum, we need to build their skills of observing and describing patterns and organising and applying this information. Students construct tables and graphs to organise data and identify patterns as early as Year 1. By Year 5, they suggest explanations for patterns they observe using evidence.

For students in Year 5, this can be:

- observing the properties of 'slime' and organising their evidence to support their conclusion that slime can be classified as a solid or a liquid
- organising their understanding of refraction and reflection of light into a Venn diagram.

For students in Year 6, this can be:

- analysing data collected on plants grown in different soils to study the effect of the physical environment on growth and survival
- organising an electronic circuit to allow electrons to flow and then sorting materials into categories based on their conducting and insulating properties.

Form and function

A relationship usually exists between the form of an object or organism and its function or use. In the primary years, students will understand the form of an object or organism to be how it looks, sounds, feels and smells, and will progress to observing and recording their observations. In upper primary years, words such as *structure of an organism* or *properties of an object* can be used to describe form.

In grasping this scientific concept, students need to be exposed to and asked to consider that there can be a relationship between the form of an object or organism and its function. Children can learn to infer the functions of things by closely observing their form. For example, they can infer what a mammal eats by observing its teeth, or which material would hold heat efficiently by studying factors affecting the transfer of heat.

For students in Year 5, this concept can be represented by:

- an exploration of the adaptations of desert animals
- the observation of properties of materials that refract light.

For students in Year 6, this concept can be represented by:

- comparing the different energy sources used for the same function—to generate electricity
- researching the properties of materials used in buildings designed to withstand earthquakes.

Science is important in developing building designs and materials that can better withstand natural disasters.

Stability and change

Are things around us constant or do they change over time? Do they change at the same rate? Does it depend on the scale we are using to look at them? This is the basic progression of this scientific concept across the primary school years with recognising, describing and predicting both stability and changes as the key skills to be developed.

Students use observations or secondary sources to identify that some things appear constant over time and that others change; these include properties of objects (for example, hardness), natural phenomena (for example, day and night) and relationships between living things (for example, bee pollination). Students progress to understanding that what may seem stable on a large spatial or time scale can show change on a small scale. Measurement of changes by students and by scientists and the organisation of the information obtained into a useable form such as tables and graphs should be a part of the study of this concept.

For students in Year 5, this concept can be studied by:

- creating a timeline to show how the scientific world has changed its understanding and theories about the solar system and the universe
- measuring and recording shadows over a day
- researching the environmental impact of ballast water from cargo ships that introduces larvae of aquatic species into new environments. These introduced species may adapt to out-compete native plants and animals.

For students in Year 6, this concept can be represented by:

- investigating the effect of different cooking processes to determine which can be described as reversible or irreversible changes of matter
- identifying the effects of erosion on a surface in the school ground or through photographs.