Science: The basics

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What is science?

Science as a whole cannot be precisely defined, but it can be broadly described by a set of key characteristics.

Science is a dynamic body of knowledge

Science provides a way to understand our very complex world. Scientific knowledge can take the form of facts, concepts, laws, theories and models that have been developed by scientists over time. Scientific knowledge is always open to question and revision. Accepted ideas may be rejected or modified as new evidence is discovered. For example, the colourful *Chalazodes* bubble-nest frog was rediscovered in India in 2011. As it was recorded that this animal had been missing since 1874, this caused scientists to revise their ideas and begin to investigate how this animal survived a deadly fungus that has killed off many amphibians worldwide. In this way scientific knowledge is dynamic.

Science is an ongoing process of discovery

Science is a process—a series of actions aimed at continually refining and expanding our knowledge of the natural world. Scientists are motivated to discover something that no one has before. Ultimately, scientific ideas must be tested—preferably with many different types of evidence by many different people. This characteristic is at the heart of all science. Typically, answering one question inspires deeper and more detailed questions for further research so that science is never 'finished'.

Science is the past and the future

Science is discovering how things worked in the past and how they are likely to work in the future. Our knowledge of science advances every day; many fundamental scientific ideas were developed years ago and modern scientists have built on the ideas of pioneering scientists. The first commercial dial-up internet access, and so the world wide web, would not have become available in 1990 if Guglielmo Marconi had not invented the radio in 1896.

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Science is reliable

Even though they are subject to change, there are key scientific understandings that have gained scientific acceptance because they are supported by many and continuing lines of evidence. These scientific explanations generate expectations that hold true, allowing us to determine how entities in the natural world are likely to behave (for example, the likelihood that a child will inherit a particular genetic disease) and how we can harness that understanding to solve problems (for example, how electricity, wire, glass and various compounds can be fashioned into a working light bulb).

Science is useful

Science is powerful and can be used in many different ways. It is almost impossible to overstate how many aspects of modern life are affected by scientific knowledge, from the routine workings of our everyday lives to global issues. Science has allowed us to view and talk to our friends on the other side of the world, to vaccinate a baby against polio, and to answer important questions, such as which areas might be hit by a tsunami after an earthquake and how to protect our crops from pests.

Science is global and collaborative

Science advances through the contributions of many different people from different cultures. People all over the world participate in the process of science, forming a global scientific community. Scientists can work alone or as a group, but communication within the scientific community is always important.

What science is not

Students can begin to grasp that science has an immense reach, from developing lasers to determining who our evolutionary ancestors were. While we open the world of science so our students are intrigued and inspired, it is also important for students to understand that science has limits—there are things that science cannot do. Science helps us answer important questions but the answers are limited to terms of natural phenomena and natural processes.

Science does not make judgements for us but it can give us information so that we as individuals can make our own judgements.

- Is euthanasia ever the right thing to do? Is this painting worth a million dollars? Science can help us learn about terminal illnesses and how our eyes relay information about colour to our brains, but scientific research will not answer moral and aesthetic questions such as these. The knowledge science provides can inform our opinions and decisions but individuals make those judgements.
- Science does not indicate what should be done with scientific knowledge. Science, for example, can tell us how to recombine DNA in new ways, but it does not specify whether we should use that knowledge to correct a genetic disease or develop a bruise-resistant apple. For almost any important scientific advance, one can imagine both positive and negative ways that knowledge could be used.

What do scientists do?

As long as there are unexplored and unexplained parts of the natural world, scientists will continue to investigate them. Observations and problems lead scientists to ask questions, to infer, to predict and to test their ideas.

Scientists actively seek evidence to test their ideas, even if the test is difficult. This could mean spending years working on a single experiment or travelling to Antarctica to measure carbon dioxide levels in an ice core.

The progress of science depends on scientists communicating their discoveries. Much scientific research is collaborative, with different people using their specialised knowledge to study different aspects of the problem. The acceptance or rejection of a scientific idea depends upon the findings of many different lines of evidence by many different people. Typically, answering one question inspires deeper and more detailed questions for further research.

Science is a dynamic, collaborative and creative human endeavour.

Science relies on clear evidence and only answers questions about natural phenomena and processes.

Observe → Ask questions → Propose hypothesis → Infer → Predict → Test hypothesis (experiment) → Draw conclusions

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.

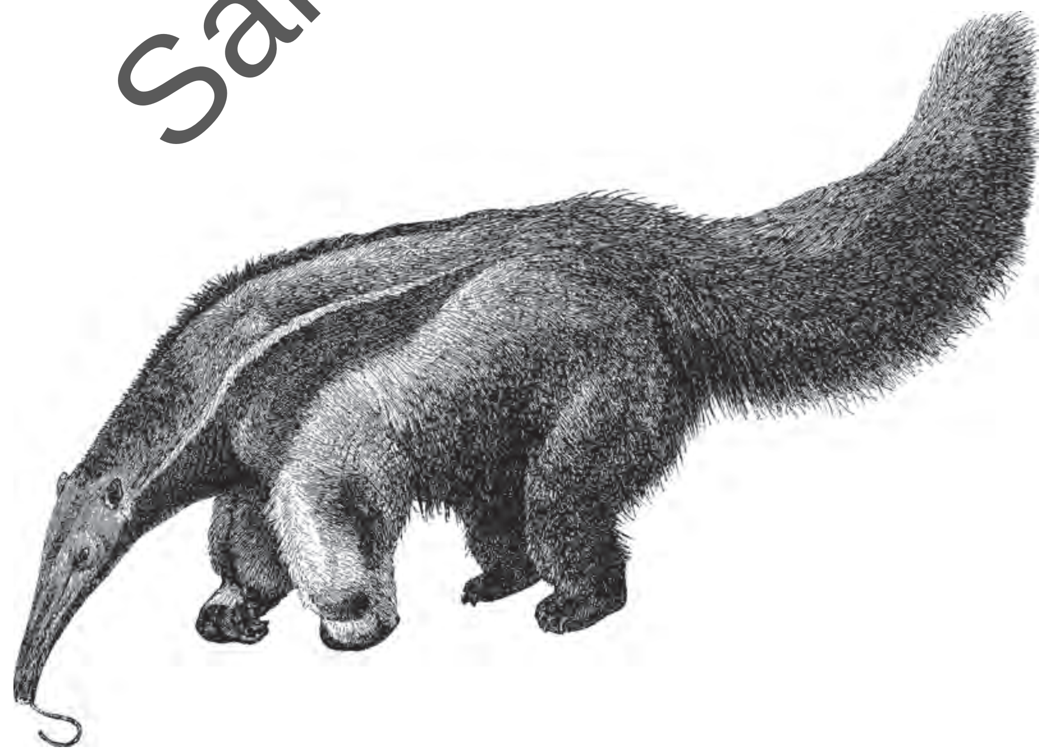
As a primary teacher, you need to have the core science knowledge and understand the concepts at least at the level you are teaching, regardless of your own scientific background and experience.

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 there are no squirrels in Australia. 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 observable properties of materials, display a large variety of different materials easily found at school, such as wooden blocks, balloons, sand, water and paper. Do not give any directions—allow students to explore the materials freely. Many examples and questions will follow their exploration.
  - Provide different pictures of animal heads and ask: 'What would they eat?' Provide pictures of animal legs and ask: 'How would they move? Why do you think so?'
  - Ask: 'How tall can you build a tower made with marshmallows and toothpicks?' Students predict, then build and measure the tower.



How would the shape of this animal's head help it to find food?

  - 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:
  - Polar bears don't live in Australia.
  - Water can change its shape.
- Create an animal that lives in the sea. Draw it, write about what it eats, how it moves, where it shelters and how it interacts with other living things. Then decide what would need to change for your animal to live on the land, too.
- 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. For example, a bandersnatch is described as a swift-moving creature with snapping jaws that can extend its neck. What would it feed on? Where could it survive?
  - *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 displays, demonstrations and role-plays. 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.

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 use this knowledge and these skills.

Elicit prior knowledge and confront preconceptions

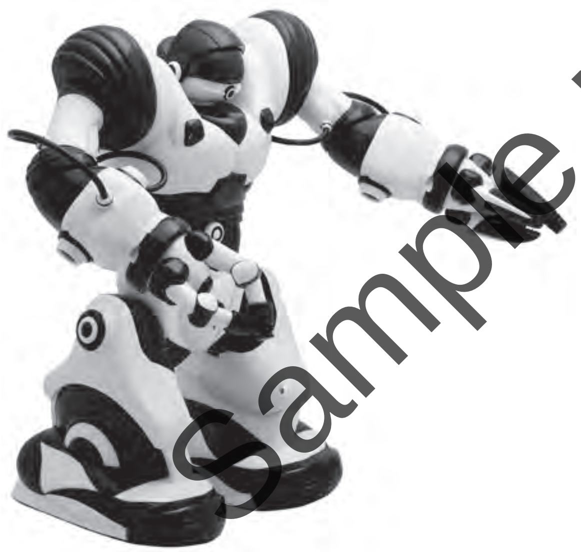
It is very important to find out what students already know about an area of science.

- 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 a student's 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.



- Walk around the school grounds. Count how many different types of plants the students can find. This will reveal what they think a plant is! Take photos and use these to look at similarities and differences between plants.
- Match pictures of adult animals to their offspring. What evidence did you use to decide these animals are related?
- 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 provoke 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 to students to think more deeply about ideas and concepts.

You can entice students to think simply 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 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 teacher. 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 the teacher's questions as well as their willingness to listen to diverse answers.

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.

- Help students as individuals or in groups to brainstorm as many questions as they can from a stimulus or provocation. Collect a master list of these questions and display them. Add to this list any questions that are asked by students during a lesson sequence, praising those who ask the questions. At the end of a lesson, ask: 'Which questions have been answered today?' Alternatively, plan to use a question as a focus for an activity or task, making sure you announce which question the class will be 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 and gives suggestions for what the teacher and 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 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, 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

Phase and purpose	Example actions to plan for
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 with teacher support
Explain The purpose is to: • clarify students' understanding • introduce information related to the concept • challenge students' understandings.	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
Elaborate The purpose is to: • extend, challenge and broaden students' understandings • 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 practise 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 after discussion with the teacher

Phase and purpose	Example actions to plan for
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 or 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