1 Investigating science

LEARNING SEQUENCE

1.1 Overview

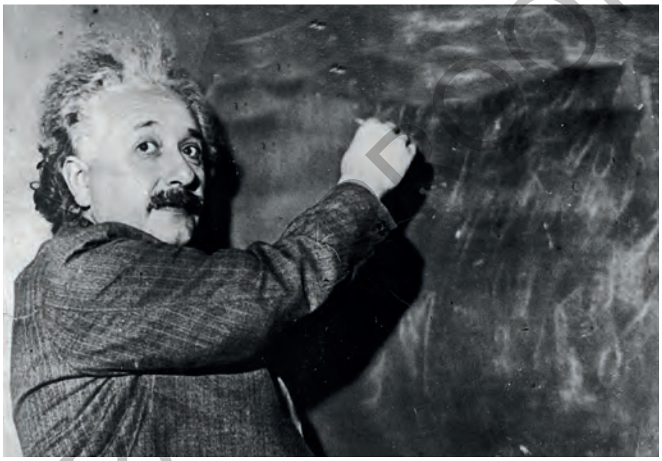
Numerous **videos** and **interactivities** are embedded just where you need them, at the point of learning, in your learnON title at www.jacplus.com.au. They will help you learn the content in this topic.

1.1.1 Introduction

Are you ethical? Does it matter? What influences your opinions, values and beliefs? How do your attitudes affect when, how and why you learn? How and why do you think the way that you do? Is it ever worth changing your mind? Why doesn't everyone think the same way as you do? Who are you and who are you yet to become?

These questions are all important to consider in science, not just when considering the content, but in the way you conduct investigations. The way you formulate investigation questions, design experiments, conduct investigations and form conclusions is often influenced by opinions, values and beliefs. It is important to ensure that these are considered to ensure accurate and valid data is obtained and findings are free of bias.

FIGURE 1.1 Einstein's theories were used to develop nuclear weapons — something he ethically opposed.



on Resources

Video eLesson Meet Professor Veena Sahajwalla (eles-1071)

Watch this video to learn about Professor Veena Sahajwalla, a leading expert in the field of recycling science, and founding director of the Centre for Sustainable Materials Research & Technology at UNSW. She is producing a new generation of green materials, products and resources made entirely, or primarily, from waste.

1.1.2 Think about science

1. Are there any examples of scientists altering their results in a scientific investigation?
2. What recent discoveries have allowed for more accurate results in investigations to be obtained?
3. Can unethical behaviour ever be justified?
4. How can simulations and models be used in investigations?
5. Is all secondary information on the internet accurate?
6. Who owns genetic material?
7. Is it your DNA or your environment that determines your beliefs and opinions?

1.1.3 Science inquiry

What makes good news?

We live in an age of information. In fact, you are continually being bombarded by it! How can you begin to make sense of all the information you receive? How can you better evaluate it? How can you incorporate this new information into what you already know to develop a better understanding of the world in which you live?

To effectively evaluate articles in the media you need to be able to determine what the facts are, and consider the type of journalism, the quality of writing and the article's ability to effectively present its message.

Read the article headlines and opening paragraphs provided, and then answer the following questions.

1. For each article, consider the following.
   a. What do you think the article is about?
   b. What type of article do you think it is? Is it:
      i. sensational ii. informative iii. entertaining iv. thought provoking?
   c. Use the internet to find further content from each article and find out more about the story by using search parameters such as the article headline and newspaper source.
   d. Analyse the language and style of writing used in the article. What kind of audience do you think this article was written for?
   e. Do you think you need to be a scientist to understand what the author is writing about?
   f. Did the article headline grab your attention and make you want to read more? If not, how could it be improved?
   g. Research one of the events or issues mentioned and write your own article about it. Collate the class articles into a journal or newspaper.
2. The first of these articles was written more than ten years ago.
   a. What types of environmental and scientific problems did people face at the time?
   b. Are they similar or different to those we face today?
   c. Use the internet to find out more about the following issues mentioned in the articles:
      i. carbon tax ii. China syndrome iii. nuclear power iv. millennium bug.
   d. How do you think people's opinions of the above issues have changed in the past ten years? Justify your answer.

That white-hot ball-bearing in the sky

Our supposedly middle-aged sun has been behaving like an adolescent of late, hurling huge clouds of particles at us after its face broke out in spots.

The Sydney Morning Herald

'Bang' when a nuclear reactor fails

There is no such thing as fail-safe nuclear power, science commentator Karl Kruszelnicki said yesterday.

'Nuclear reactors are not fail-safe. They won't fail in a safe way. They can go bang as Chernobyl did,' Dr Kruszelnicki said.

Herald Sun

Nuclear crisis is no longer fiction

The nightmare scenario for Japan's crippled nuclear power plants is the so-called China syndrome.

The Hollywood movie *The China Syndrome* portrayed a near-meltdown of nuclear fuel rods in a US reactor.

Herald Sun

Millennium bug melee misses the true degree of our challenge

Tim Flannery's 1000-year carbon concession is a straw man that will no doubt burn brightly throughout the highly contested carbon tax debate.

The Australian

on Resources

eWorkbooks	Topic 1 eWorkbook (ewbk-6530) Student learning matrix (ewbk-6534) Starter activity (ewbk-6532)
Practical investigation eLogbook	Topic 2 Practical investigation eLogbook (elog-0737)
learnon	Access and answer an online Pre-test and receive **immediate corrective feedback** and **fully worked solutions** for all questions.

1.2 Thinking flexibly

LEARNING INTENTION

At the end of this subtopic you will be able to explain and provide examples of thinking (both flexibly and critically) in science, and describe the influence of attitudes and behaviours to the refinement of theories over time.

1.2.1 Thinking with an open mind

'One thing only I know, and that is that I know nothing.' This statement is often linked to a Greek philosopher called Socrates (470–399 BC), who had a major impact on Western thinking and philosophy. This statement, however, also goes against what is commonly thought about science and scientists. Some consider that science will always have the answers and that scientists know all. Not only is such a belief untrue, it is also potentially dangerous. Thinking flexibly and with an open mind are better traits for a scientist to possess. The history of science and philosophy is littered with theories that at one time were considered to be answers, but were later discarded.

FIGURE 1.2 Socrates, a famous Greek philosopher

In science, it is important that you are not just able to think critically, but also able to think flexibly.

Being able to think critically involves being able to carefully consider information provided to you to help guide decision-making. Thinking flexibly involves being able to consider different points of view.

Science doesn't just involve conducting practical investigations and recording and analysing results. It is important to consider ethics, attitudes, opinions, values and beliefs. Being able to think flexibly and appreciate these different viewpoints is important because it allows you to think in a critical way and strengthen the conclusions you are able to draw.

Being able to think both critically and flexibly has allowed for some of the most exciting and amazing scientific discoveries.

1.2.2 Making judgements

Opinions, values and attitudes involve making **judgements** about the desirability of something, whereas beliefs usually do not. Your **values** may involve making personal judgements and represent a deeper commitment than an attitude would. Values also act as standards in your decision making. **Opinions** can be expressed as a point of view that is based on known facts or available information. Although **beliefs** reflect what we think and know about the world, they do not have to be based on fact. While

judgements opinions formed after considering available information

values represent a deep commitment to a particular issue and serve as standards for decision making

opinions making judgements about the desirability of something

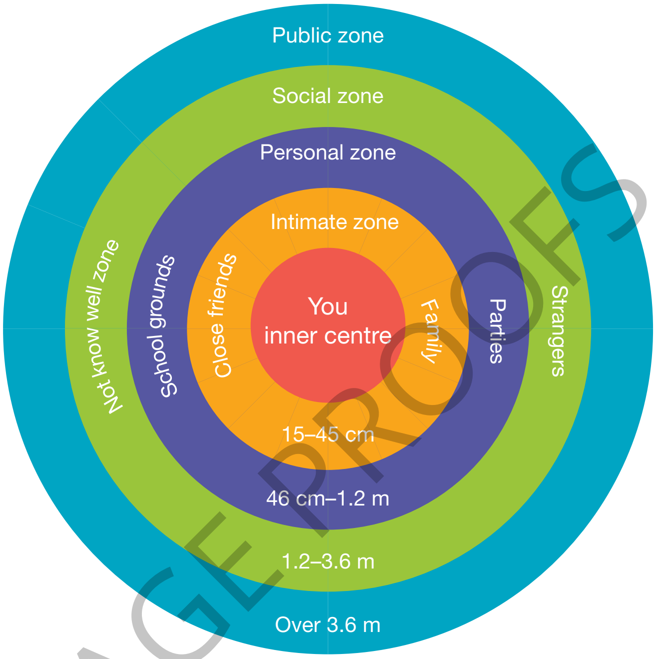
beliefs feelings or mental acceptance that things are true or real you may see the world through the lenses in your eyes, your perceptions are filtered through your beliefs and assumptions.

Other lenses

Your family, cultural and social environments also play a part in how you perceive the world. Your attitudes, values and beliefs may be quite different due to the influence that these factors have on how you shape and organise your understanding of what happens around you. The time that you live in is also important. Imagine the effect this has had on scientists throughout different times in history.

Our attitudes can also be expressed by the distance that we place between ourselves and others. **Proximate rules** determine the physical distance (in zones) that is comfortable between people, depending on their relationships (see figure 1.3).

FIGURE 1.3 Proximate rules and the comfortable distance of people in different zones.



1.2.3 Why do we need to consider attitudes and opinions in science?

What is now considered science may also be described as a branch of philosophy. This branch is involved in trying to explain our observations from both inside and outside our bodies. There are many different ways to analyse the tree of knowledge that we call science. Three of these ways are:

- **inductionism** — suggests that scientific knowledge is proven knowledge and that large amounts of first-hand data, unbiased observations and a structured method can lead to theories that can become universal laws
- **falsification** — the philosopher Karl Popper (1902–1994) believed that no theory was ever proven beyond doubt. He believed that theories were just educated guesses and if they failed rigorous testing they should be thrown out.
- **paradigms** — or ways of thinking. Thomas Kuhn (1922–1996) saw science as being generated by basic theories or groups of ideas that are followed and defended by scientists. These paradigms are accepted even when data suggest that they may not be true. Only when the evidence against the theory becomes too great does the paradigm change, to be replaced by another, until it too is replaced.

FIGURE 1.4 Karl Popper

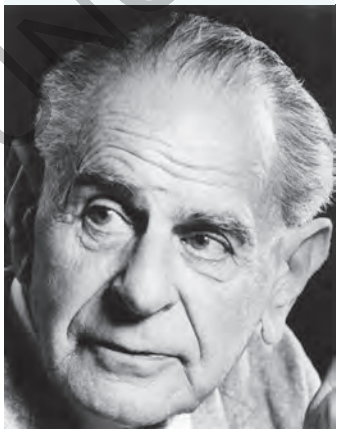
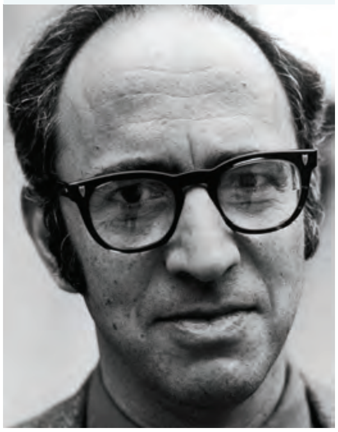


FIGURE 1.5 Thomas Kuhn



inductionism a theory stating that with enough evidence, scientific theories can become universal laws

falsification a theory stating that no theory is ever proven beyond all doubt

paradigms generally accepted perspectives, ideas or theories at a particular time

proximate rules govern the physical distance that is comfortable between people

elog-0739

INVESTIGATION 1.1

What are my values and beliefs?

Aim

To reflect on and make decisions regarding a variety of claims

Method

1. On your own, score each of the following statements on a scale of 0 to 4 where 0 = strongly disagree and 4 = strongly agree.

0	1	2	3	4
Strongly disagree	Disagree	Neutral	Agree	Strongly agree

- Books are better than movies.
- Fiction is more interesting than non-fiction.
- Only wealthy students should get an education.
- Science classes should include science fiction stories.
- If something is too hard, it's not worth trying.
- Students who get below 50 per cent on a test do not deserve an education.
- At 15 years of age you have a sense of who you are.
- You are weak if you feel the need to belong.
- If you failed before, don't bother trying again.
- You can have ownership without possession.

2. For three of the statements in step 1, share your opinions by being involved in constructing a class 'opinionogram'.
   a. Divide the classroom into five zones, and assign a score of 0 to 4 to each zone.
   b. Each student now stands in the zone that indicates their score for the first statement.
   c. Discuss the reasons for your opinion with the students in your zone.
   d. Suggest questions that could be used to probe students in different opinion zones.
   e. With students in other zones, discuss their views and share with them the reasons for your opinion.
   f. Reflect on what you have heard from others. Decide if you want to change positions and, if so, change. Give a reason for why you are changing.
   g. Repeat steps (b)–(f) for two other statements.

Results

1. Outline your score for each of the given statements.
2. Construct graphs showing the opinion scales for each statement and comment on any observed patterns.

Discussion

1. a. Reflect on what you have learned about the opinions and perspectives of others.
   b. In your teams, discuss any insightful comments, ideas or opinions.
   c. Suggest questions that could be used to more closely probe reasons for your classmates' opinions. Share these probing questions with your class.
2. Suggest how you have demonstrated resilience, reflectiveness, responsibility and resourcefulness during this activity. Comment on things that you may change if you were to do the activity again.

Conclusion

Summarise your findings about opinions on different values and beliefs.

1.2.4 Communicating attitudes through paralanguage

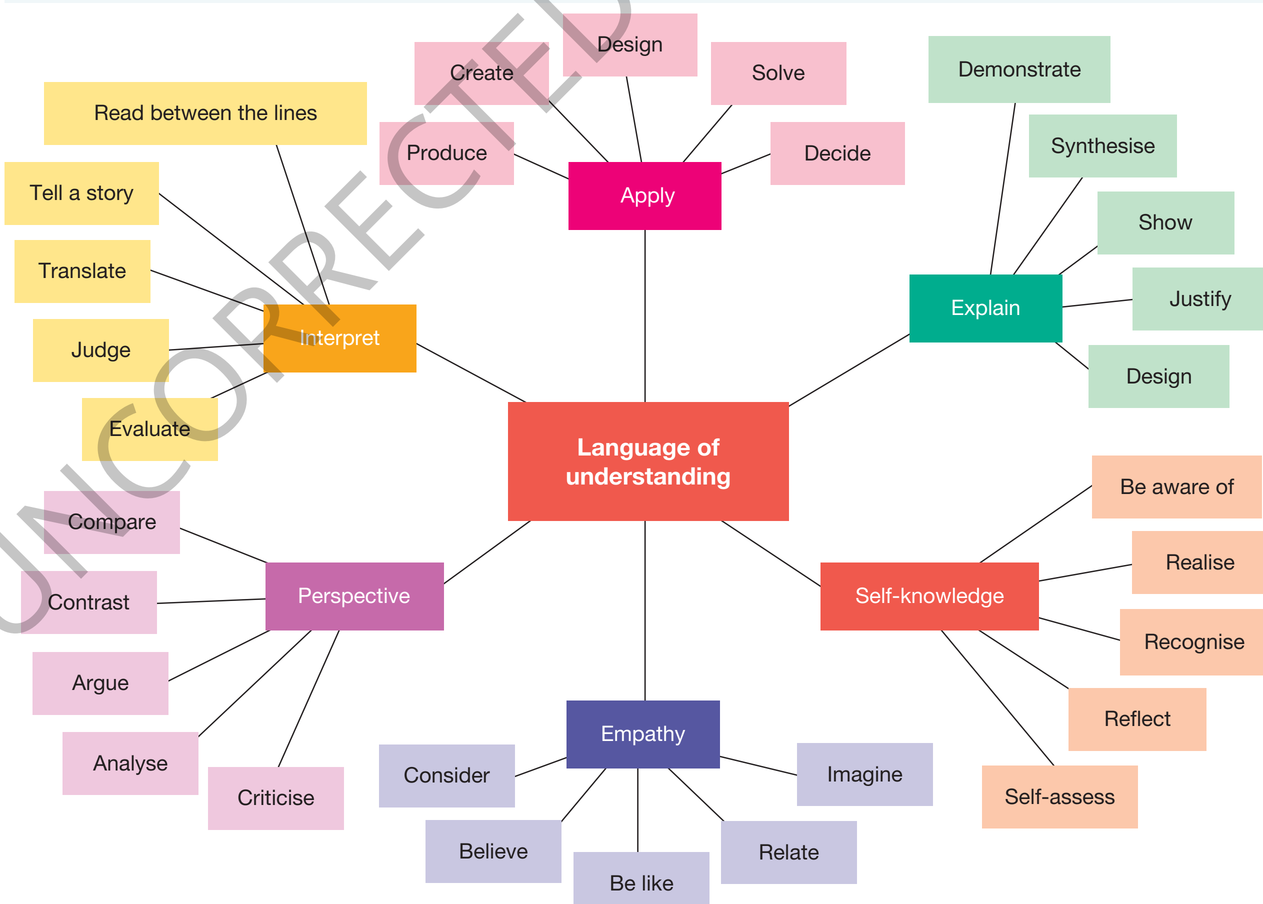
Attitudes can be communicated both verbally and non-verbally. We express them in the words that we speak, our posture, our use of space, gestures, facial expressions, and the tones, inflections, volume and pauses in our speech. These are examples of **paralanguage**. Paralanguage is communicating your specific meaning through the way that you speak, as well as what you say.

paralanguage parts of communication used to modify meaning and show attitudes

int-8153

ewbk-6535

FIGURE 1.6 The language of understanding



The language of understanding

Who are you and who are you yet to become? How can your use of language and non-verbal communication give the right impression about who you are? How do your attitudes affect when, how and why you learn? Can you remember different types of learning in different ways? How can you make your learning and understanding more effective?

Thinking tools

There are many different ways to organise and communicate your thoughts. These thinking tools help you to improve your communication of ideas, organise thoughts, reflect attitudes and display ideas. Some examples include:

- mind maps
- priority grids
- SWOT analysis
- matrices
- cycle maps
- fishbone diagrams.

These Thinking tools will be further explored in subtopics through Science Quest 10.

on Resources

eWorkbook Summary of different thinking tools (ewbk-6537)

1.2.5 Refinement of theories

What is a theory?

A **theory** is a well-supported explanation of a phenomena, based on investigations, research and observations. In science, theories are often tested using the scientific method.

It is important to note that theories are referred to as well-supported explanations, rather than proven explanations. Theories are formulated based on information available at the time, and provide an explanation of a phenomena.

Theories can change overnight, or take a very long time to change. Theories that were once popular and well accepted may be discarded when too much evidence builds up against them. They are replaced by a theory which better fits the observations.

As our ability to conduct investigations improves over time, our ability to interpret results and make observations is also changing. New technology has allowed us a greater understanding of science than ever before, thereby allowing us to adapt and adjust previously well-supported theories.

However, in 5, 10 or 100 years time, new observations may replace the theories that are currently supported today.

theory a well-supported explanation of a phenomenon based on facts that have been obtained through investigations, research and observations

on Resources

Video eLesson Dark matter labs (eles-2688)

SCIENCE AS A HUMAN ENDEAVOUR: Refining theories in astrophysics

Until recently, it was accepted that about 23 per cent of our universe was made up of stuff that we can't even see. This invisible dark matter is said to lurk in the hearts of galaxies and keep the outermost stars from flying off into the void. It is thought to be responsible for the appearance of clusters of galaxies. But what if this isn't the case?

Newton's theories are again being questioned. A growing number of astrophysicists support a controversial new theory called Modified Newtonian Dynamics (MoND), which has led to some surprising predictions about the evolution of the universe. Previously, galaxies were thought to have formed from relatively dense pockets of matter with dark matter holding them together. The laws of the MoND theory suggest a different picture is possible. If correct, this theory could overthrow the established view of gravity and dark matter. These two areas underpin almost everything known about astronomy. MoND may also lead to a rethinking of Einstein's theory of relativity.

TABLE 1.1 The changing ideas of the Universe

1933	Fritz Zwicky coins the term 'dark matter' to describe unseen mass or 'gravitational glue' in galaxy clusters.
1978	Astronomers show that many galaxies are spinning too quickly to hold themselves together unless they are full of dark matter.
1983	Mordehai Milgrom publishes a modified gravity theory called MoND. It explains why galaxies don't fly apart without using dark matter, but remains at odds with Einstein's relativity.
1990s	Studies of galaxies and galaxy clusters show that their gravity bends light more strongly than is expected without dark matter. MoND researchers start devising improved theories to explain extra light bending.
1994	Jacob Bekenstein and Roger Sanders prove that any theory that resolves the light-bending issue and meshes MoND with relativity must involve at least three mathematical fields.
2000	New data on the cosmic microwave background reinforce the standard, dark matter picture of the universe.
2004	Jacob Bekenstein devises a version of MoND that is consistent with relativity.
2005	Constantinos Skordis and others show that relativistic MoND provides a good fit to the microwave background data.

CASE STUDY: Newton (1643–1727) and Descartes (1596–1650)

Newton's theory of universal gravitation stated that everything was attracted to everything else. This would mean that the sun's gravity would keep the Earth and other planets in orbit. Descartes, however, did not think that force could be transmitted through empty space and suggested that the Earth was in some kind of whirlpool that revolved around the sun.

Another difference between these theories was their predictions about the shape of the Earth. Newton's theory suggested that the Earth would be flatter at the poles and fatter at the equator due to the effects of gravitational force. Descartes' theory suggested the opposite. In 1737, two expeditions left France to travel around the world and measure the curvature of the Earth to resolve the dispute. Upon their return, both expeditions provided measurements that supported Newton's prediction.

FIGURE 1.7 Newton and Descartes differed in their opinions on gravity and forces.

ACTIVITY: Exploring the life and times of Newton and Descartes

Find out more about the life and times of Newton and Descartes. Write a newspaper article of the times to describe their rival theories.

How do refinements of existing theories come about?

Theories are refined and adapted for a variety of reasons. This can be through:

- observations made in carefully planned laboratory-based or field-based experiments
- critical reinterpretation of previously accepted facts, producing a new framework
- new technologies that allow for changes to understanding and more depth of knowledge.

SCIENCE AS A HUMAN ENDEAVOUR: Einstein's impact

Albert Einstein's (1879–1955) contribution to modern physics is unique. Over a hundred years ago, when he was only 26 years old, he published a series of original theories that changed the way we see the universe. He published revolutionary ideas on the photoelectric effect, special relativity and Brownian motion.

In his study of Brownian motion, Einstein confirmed the existence of atoms. While other scientists were debating whether light was a particle or a wave, his theory of the photoelectric effect, which described the interaction of light and matter, suggested it was both.

His theory of special relativity examined the nature of space and time. The relativity theory is called 'special' because it doesn't include the effects of gravity. He showed how space and time could mix and match depending on your point of view. Special relativity stated that an atomic clock travelling at high speed in a jet plane ticks more slowly than a stationary clock. His theory also explained how an object could shrink in size and gain mass at the same time. It was this theory that led to the famous equation $E = mc^2$ which links energy and matter. This led to the realisation that huge amounts of energy are released in nuclear reactions. While this has provided some benefits, it has also led to detrimental applications such as the production and use of nuclear weapons.

FIGURE 1.8 Einstein's 1939 letter to President Roosevelt

Albert Einstein
Old Grove Rd.
Nassau Point
Peconic, Long Island
August 2nd, 1939
F. D. Roosevelt,
President of the United States,
White House
Washington, D. C.

Sir:

Some recent work by E. Fermi and L. Szilard, which has been communicated to me in manuscript, leads me to expect that the element uranium may be turned into a new and important source of energy in the immediate future. Certain aspects of the situation which has arisen seem to call for watchfulness and, if necessary, quick action on the part of the Administration. I believe therefore that it is my duty to bring to your attention the following facts and recommendations.

In the course of the last four months it has been made probable — through the work of Joliot in France as well as Fermi and Szilard in America — that it may become possible to set up a nuclear chain reaction in a large mass of uranium, by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

This new phenomenon would also lead to the construction of bombs, and it is conceivable — though much less certain — that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, might very well destroy the whole port together with some of the surrounding territory. However, such bombs might very well prove to be too heavy for transportation by air.

FIGURE 1.8 A mushroom-shaped cloud is often associated with a nuclear explosion.

ACTIVITY: Einstein's letter to President Roosevelt

a. Find out what prompted Einstein to write the letter to President Roosevelt.
b. What were Einstein's thoughts on this application of theories that he had been involved in?
c. If you were in Einstein's situation, suggest how you would feel and what you would do. Present your thoughts in a letter that you would write to a close friend.

1.2.6 Shifting tides

What are the laws of nature? A physical law may be a hypothesis that has been confirmed by experiments so many times that it becomes universally accepted. Current research and advances in technology are increasingly leading some to question the constants or laws that have formed the basis for our science laws (including Einstein's theory of special relativity).

It is good to question what we think we know. Sometimes, the changes in technology and in our attitudes, values and beliefs can alter what we previously thought was a given. Questioning your assumptions can also lead you to deep insights.

on Resources

Video eLessons Theoretical physicists of the twentieth century (eles-2687)
Australia's top scientists (eles-1079)
Hesperides science (eles-1078)

1.2 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 2, 3, 8	Questions 1, 4, 6, 9	Questions 5, 7, 10

Remember and understand

1. Describe the difference between opinions and beliefs.
2. Fill in the word in the following sentence:
   ____________ suggests that scientific knowledge is proven knowledge and that large amounts of first-hand data, unbiased observations and a structured method can lead to theories that can become universal laws.
3. Identify each of the following statements as true or false. Justify your responses.
   a. Attitudes are a combination of feelings, beliefs and actions.
   b. Beliefs involve making judgements about the desirability of something whereas opinions, values and attitudes do not.
   c. Opinions can be expressed as a point of view based on fact whereas beliefs reflect what we think and know about the world, but don't need to be based on fact.
   d. The history of science and philosophy is littered with theories that at one time were considered to be answers, but were later discarded.
   e. Laws in the new theory of Modified Newtonian Dynamics (MoND) could overthrow the established view of gravity and dark matter, question what we currently know about astronomy, and lead to the rethinking of Einstein's theory of relativity.
   f. It can be useful for scientists to question their assumptions.

4. Match the language of learning categories with the appropriate question.

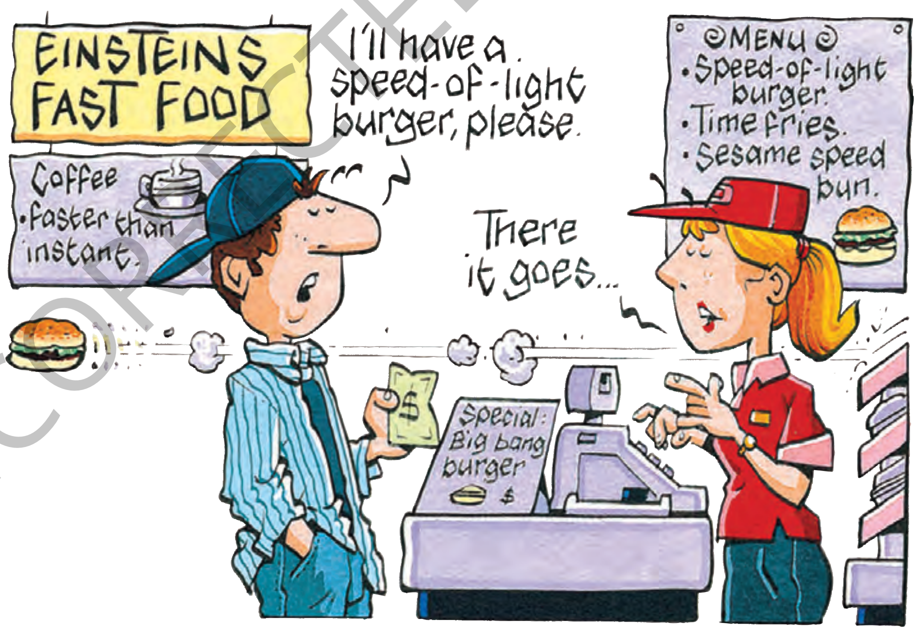
Language of learning	Questions
a. Apply	A. What does this mean?
b. Empathy	B. What are others aware of that I am missing?
c. Explain	C. What are my weaknesses? How do I best learn?
d. Interpret	D. How and where can I use this knowledge?
e. Perspective	E. Is it reasonable? Whose point of view is this?
f. Self-knowledge	F. Why is it so? How does it work?

Apply and analyse

5. A bias is a preference that may inhibit your impartial judgement.
   a. Give an example of how you are biased.
   b. Bias may be revealed by comments that are exaggerations, generalisations, imbalanced opinions stated as facts or emotionally charged words. Look through online articles and select two articles that show examples of bias. Bring these articles to school and discuss the bias with your class.
   c. Suggest why it is important to know your biases.
6. Research one of the following scientists and outline a theory that they have been involved in constructing: Charles Darwin, Michael Faraday, Ernest Rutherford, Jean-Baptiste Lamarck, Francis Crick, Gregor Mendel, Albert Einstein.
7. Research and describe four examples of scientific theories that are no longer in favour.

Evaluate and create

8. Suggest ways in which you can use language positively when you are communicating with others.
9. a. Carefully examine the cartoon shown and then research Einstein's theory of relativity.
   b. On the basis of your findings, explain which ideas the cartoonist is trying to incorporate. Suggest how the cartoon could be improved.



10. Reflect on Einstein's quote 'Imagination is more important than knowledge'. In terms of science, what is your opinion on this statement?

Fully worked solutions and sample responses are available on your digital formats.

1.3 Science and ethics

LEARNING INTENTION

At the end of this subtopic you will be able to explain the influence of ethics in science and describe how this is influenced by goals, rights, needs and duties.

1.3.1 Difficult decisions

If you really wanted something, how far would you go to get it? What wouldn't you do?

If you wanted the lead in the school play, what would you do? Might you take up music lessons or buy the selecting teacher gifts? How about stealing a script so you can get that bit of extra practice in?

1.3.2 Goals, rights, needs and duties

Goals and rights

Shona in figure 1.9 wants to get a place in the school musical. This is Shona's **goal** — it is something she wants to achieve. However, Shona does not have a **right** to a place in the musical; although, as a student of the school, she does have the right to try for a place. A right is something we have if we can expect to be treated in a certain way, no matter what the consequences. A right is different from a need.

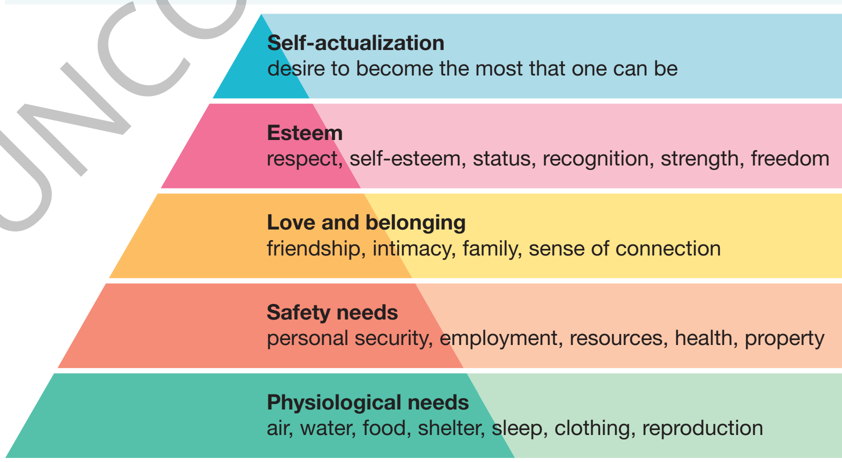
FIGURE 1.9 What are the goals, rights, needs and duties of Shona?

Needs and duties

A **need** is something we require. We all have the need to feel we are doing something worthwhile. If Shona gets a place in the musical, she will have a **duty** towards her fellow actors. We often think of having a duty as being required to act in a certain way; for example, telling the truth. Shona may have several duties, such as learning her lines and attending rehearsal sessions.

Needs are often outlined using Maslow's hierarchy of needs, as shown in **FIGURE 1.10** .

FIGURE 1.10 Maslow's hierarchy of needs



goal something that you want to achieve

right something you feel that you are entitled to

need something that you require

duty moral obligation or responsibility

The most important needs are at the base of the hierarchy and are fundamental and primary needs.

Needs are something we require, and are different to wants, which is something we desire.

DISCUSSION

The COVID-19 pandemic brought to light the continual debate between wants and needs, and how opinions around these differ greatly between individuals.

The line between wants and needs often becomes more blurred for individuals in times of crisis, particularly in times of lockdown and economic uncertainty.

Discuss with those around you how and why individuals might view wants and needs differently in times of crisis, and describe four examples of how thoughts on wants and needs differed between individuals during the COVID-19 pandemic.

Duties versus goals

Duties often derive from goals and rights. For example, if you are accused of a crime and appear in court, you have a right to a lawyer, regardless of whether you are innocent or guilty. Your lawyer has a duty to try to get you acquitted — this is your lawyer's goal.

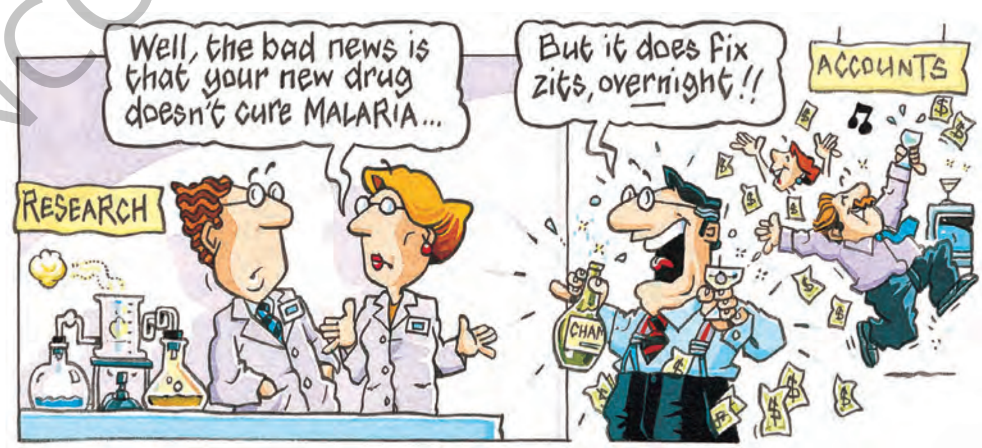
Some situations can become very complicated. For example, a dying man asks his doctor not to keep him alive any longer. Does the doctor have a duty to carry out the man's wishes because of the man's right to decide when and how to die? Or does the doctor have a duty to ignore the man's wishes because of the goal of preserving life?

How are these related to science?

Scientists are also influenced by goals, rights, needs and duties. A goal of many scientists is to investigate the world around us and attempt to develop explanations of why and how it behaves as it does. Some scientists may also consider this to be their duty or the fulfilment of a need — or even their right to do so!

Science is often used to help us answer questions about how we can apply this knowledge. For example, if we want to know the effect of a particular diet, drug or some other factor on athletic performance, science can provide some answers.

FIGURE 1.11 Should science delve into the mysteries of life? Who decides what will be researched and how discoveries will be used? Is science all about fame and fortune, or is it about seeking the truth? What is your image of science?



The goals, rights and duties of scientific investigations become less clear when science is asked to provide us with answers about what we should do and how we should behave. **Ethics** are involved in shaping our ideas about what is right and wrong.

1.3.3 Ethics

Ethics involve your moral values. While some ethical values are universal and widely accepted around the world, other ethical values vary — not only between countries, but also between different religions and communities. They may also vary within families, between different generations and throughout different times in history.

A particular scientific investigation or application of technology may be acceptable to one group of people, but highly offensive to another. Different belief systems might give rise to different ethical principles and practices. These may influence the types of scientific investigations performed and the ways in which they are conducted.

FIGURE 1.12 Ethics are around the idea of moral choice.

Ethical values vary between countries, religions, communities and individuals — even between members of the same family. For example, capital punishment, the execution of a person for committing a crime, is considered by some to be right and by others to be wrong.

Science interacts with ethics in several ways, including:
- affecting the way in which science is conducted
- affecting the types of scientific research carried out
- in the conflict or match between scientific ideas and religious beliefs
- providing scientific community practices that act as a model for ethical behaviour.

Five key principles are involved in ethics:
- Integrity, truthfulness and transparency: honest reporting of any findings.
- Justice: equal access to benefits for various groups and all individuals are treated fairly and equitably.
- Beneficence: maximising benefits to an individual (do more good than harm).
- Non-maleficence: minimising harm caused to individuals.

ethics the system of moral principles on the basis of which people, communities and nations make decisions about what is right or wrong

- Respect and autonomy: valuing living things, both human and non-human, including customs, decision-making and autonomy. For living things that cannot make decisions, it ensures they are protected as required. This also includes ensuring that confidentiality is maintained.

It is important to consider ethics in conducting research and investigations. This includes in scientific investigations, medical research and in agriculture.

DISCUSSION

Discuss the following statements with your team.

- Scientists have a responsibility to consider the wider effects of their research.
- Individuals can influence the type of scientific research performed.
- The government controls what is done with scientific research.
- Companies should have total ownership of any research they financially support.

on Resources

eWorkbooks Science and ethics (ewbk-6539)
Difficult decisions (ewbk-6541)

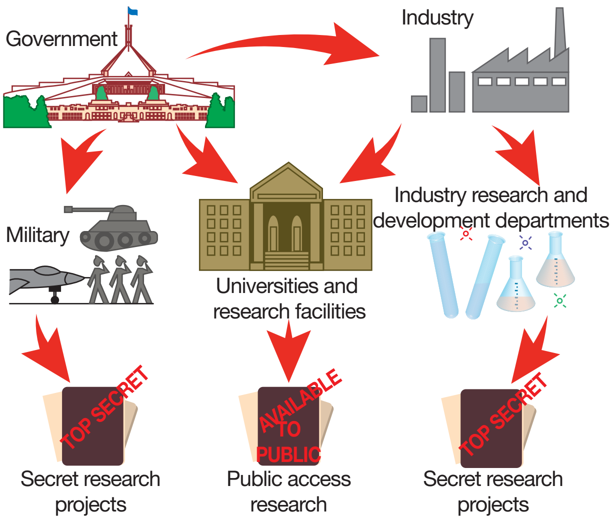
Scientific research

Scientific research is responsible for discoveries that have been of great value to humankind. A quick glance around us shows lots of products of science that increase our efficiency and improve our lifestyles. Scientific research is also responsible for discoveries that have had negative effects on individuals, communities, countries and our environment. But when we talk about responsibility, is it science and the discoveries that are responsible, or is it the way in which the knowledge has been used? Who is responsible for how the knowledge is used? These issues are relevant to many examples of current scientific research.

1.3.4 Medical research

Medical research can be driven by need or greed. Sometimes it can provide important information, knowledge and understanding that can not only improve life, but also save it. Sometimes it can achieve this goal as well as make a lot of money for those involved in the research or its funding.

FIGURE 1.13 An example of the movement of money in science



Taking risks

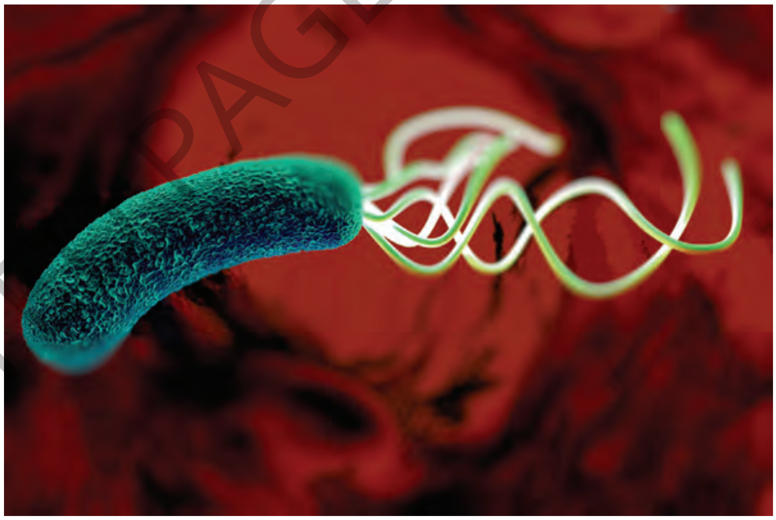
If acid inside your stomach eats into your stomach lining, an ulcer can result. This very painful condition can also cause bleeding and can be difficult to treat. In some cases, surgery is required. It was thought that lifestyle factors, such as spicy food and stress, were key factors that triggered these painful ulcers.

In 2005, Australian scientists Barry Marshall and Robin Warren received the Nobel Prize in Medicine for their research on stomach ulcers. They showed that the actual cause of many stomach ulcers was not lifestyle, but the presence of the bacteria *Helicobacter pylori*. This revolutionary finding meant that ulcers could be treated with antibiotics.

Their discovery, however, was not recognised for a number of years. Their ideas faced strong opposition from the scientific community. Firm in his conviction that these bacteria were the real cause of ulcers, and that they could be easily cured by antibiotics, Marshall took a drastic step. He drank a container of *Helicobacter pylori* to infect himself! Fortunately for him (and us), although he experienced considerable discomfort, he was cured by antibiotics.

FIGURE 1.14 An illustration of a stomach ulcer

FIGURE 1.15 *Helicobacter pylori* bacteria in the human stomach cause stomach ulcers.



on Resources

Video eLesson Heliobacter pylori bacteria (eles-2691)

DISCUSSION

Discuss the following with those around you and share your ideas with the class.

- Were Marshall's actions ethical?
- There are strict regulations on experimentation on humans. Did this give him the right to infect himself?
- Was it his duty?
- Apparently Marshall had carried out a risk assessment and had decided that the benefits of experimenting on himself outweighed the risks involved. Do you agree with his conclusion?
- If you were him, is this what you would have done?

Drug trials

Lots of ethical issues are involved in drug trials and how these types of trials are conducted.

It is important in drug trials that all participants are aware of any risks involved, have full autonomy in the process, and are able to withdraw if they choose.

Often opinions differ in how drug trials should be conducted.

FIGURE 1.16 Different opinions of individuals on drug trials

A The realist

Drug trials are expensive and will add to the cost of the drugs, which is already high.

B The humanist

Testing takes time and we already know that these drugs have been effective. There are people dying who are in need of these drugs now.

C The ethicist

We have a responsibility to test these drugs to ensure that they are completely safe for all members of society. The most rigorous testing should always be carried out.

Sadly, there are many historical cases of drug trials that were not conducted ethically, such as:

- the Tenofovir trials on HIV in which individuals were given information in English, when they were French speakers, so were not informed of risks
- the Tuskegee syphilis experiments in which some individuals were deliberately infected and given **placebos**, despite being informed they were given the treatment
- the TGN1412 trials in the United Kingdom, in which individuals were given anti-inflammatory drugs but were not properly informed of the risks involved.

placebo a medicine or procedure that has no therapeutic effect, used as a control in testing new drugs

CASE STUDY: TGN1412

A new drug, TGN1412, was designed to treat leukaemia and certain autoimmune diseases such as rheumatoid arthritis. In rheumatoid arthritis, the body's immune system turns upon its own tissue and attacks it. TGN1412 is a powerful antibody that works by binding to the immune system's T cells, causing them to activate and multiply rapidly.

TGN1412 made headlines in 2006 after its first trial on human subjects. It was given to six healthy young men in the United Kingdom and caused severe adverse reactions that required intensive care. One man's head swelled to three times its normal size, causing excruciating pain. The worst affected trial volunteer was 20-year-old Ryan Wilson, who was in a coma for three weeks after taking the drug.

Drug trial volunteers are mainly young people, and many are backpackers and students who are attracted to the payments made by pharmaceutical companies. Other controversies have arisen following drug trials in Nigeria and India, where it was unclear whether patients had given their informed consent.

DISCUSSION

How much information should be given to drug trial volunteers? Who should be involved in trialling new drugs? Discuss this and share your thoughts with others.

Applications of medical research

Public institutions, such as universities, carry out medical research to increase our understanding and contribute to the development of possible solutions to current or potential future problems. Some of this research is linked to making money and some purely for the knowledge and understanding that it provides.

Medical research in private companies may also contribute to our knowledge, understanding and problem solving — their key goal, however, is to make a financial profit. The type of research being funded may be influenced more by its money-making potential than by its potential to reduce human suffering and improve quality of life.

CASE STUDY: Ethics around future vaccinations

In the past century, variations of the bird flu virus H5N1 have been responsible for pandemics in which large numbers of humans died. The viruses H1N1 in 1933, H2N2 in 1957 and H3N2 in 1968 preceded the appearance of H5N1 in 1997.

Some articles in the media suggest that the offspring of a modified H5N1 virus may contribute to the end of the human race. Scientists have stated that if there is mixing of the genetic material of the human flu virus with this bird flu virus, it may create something that our immune systems can't fight. In such a situation, millions of people may die. Individual genetic variations may be a key factor in the outcome of who will live and who will not survive.

Our main chance of survival may be the development of a vaccine against a virus that does not yet exist. It is another example of how possible need can direct the journey of scientific discoveries. In this frenzy to create vaccines, many issues arise. How much information should be shared with companies, governments, countries and the public? Will only those who can afford treatment receive it? Is this the new form of natural selection? Who is responsible for taking control and regulating the research and its discoveries?

DISCUSSION

Only about 75 per cent of the world's children are being vaccinated against viruses such as measles, whooping cough and chickenpox. Some new vaccines; for example, against hepatitis and meningitis, have hardly been used at all. If these vaccines can reduce the chance of others becoming ill or dying from particular diseases, who has the responsibility to make sure that they are effectively used? Should the individual take responsibility, or should it be the community, government or scientists?

1.3.5 Animal testing

Is it ethical to use animals in scientific research? Animals are used in scientific research to test the effects of cosmetics, different surgical techniques, types of disease treatments, and to find out more about how their and our bodies function. During some of this research animals may experience pain, suffering and even death. There are many ethical issues related to the use of animals in scientific research, the types of animals used and whether the research itself is ethical.

1.3.6 Ethics in agriculture

With an increasing global human population comes the need for an increased food supply. Traditional plant breeding methods are being replaced with new technologies. One of these is the use of **genetic modification** (GM). This technology enables plants to be designed with features that increase crop yields and quality.

Some applications of genetic modification enable the development of crops that are resistant to herbicides (for example, canola), can make their own pesticides (for example, cotton) or contain added nutrients (for example, rice).

There is considerable debate about the use of genetic modification because it involves changing the plants at a molecular level: the actual DNA of the plant is modified. This technology can involve moving genes between different species, so the resulting plant is transgenic (contains DNA from different species).

genetic modification the technique of modifying the genetic structure of plants, making it possible to design plants that have certain characteristics

FIGURE 1.17 Many ethical considerations need to be made around animal testing.

FIGURE 1.18 Genetic modification is used to increase crop yields and quality.

DISCUSSION

Discuss the following questions in relation to genetically modified foods in agriculture.

- Is it right to interfere with nature?
- Does the addition of an animal gene to a plant make it suitable for vegetarians?
- Should GM foods show this status on their labels?
- Who should receive the profits?
- Who has ownership of the modified plants?

elog-0741

INVESTIGATION 1.2

Where do I stand on ethical issues in science?

Aim

To reflect on and make decisions regarding a variety of ethical issues in science

Method

1. On your own, score each of the following statements on a scale of 0–4, where 0 = strongly disagree and 4 = strongly agree.
   - Immunisation of children should be compulsory.
   - Genetic manipulation of food crops and animals should be illegal.
   - IVF technology should be publicly funded.
   - Nuclear reactors should be built in each Australian state and territory.
   - Cosmetics should be tested on other animals prior to their availability to humans.
   - The development of new drugs should be done by non-profit organisations rather than those that may make a profit.
   - If an effective but expensive drug is available to cure a life-threatening disease, it should be available to everyone, not just those who can afford it.
   - Genetically modified food should be clearly labelled as such.
   - Close relatives of humans, such as monkeys and chimpanzees, should not be used as animals in scientific research that tests the effectiveness of treatments against various diseases.
   - Scientists should be allowed to experiment on themselves.
2. For at least three of the statements, share your opinions by being involved in constructing a class 'opinionogram'.
   a. Divide the classroom into five zones, and assign a score of 0 to 4 to each zone.
   b. Each student should stand in the zone that indicates their score for the first statement.
   c. Have a member of the class record the number of students at each point of the scale.
   d. Discuss the reasons for your opinion with the students in your zone.
   e. Suggest questions that could be used to probe students in different opinion zones.
   f. Share reasons for your opinion with students in other zones and listen to their reasons for their stance.
   g. Reflect on what you have heard from others. Decide if you want to change positions and, if so, change. Give a reason for why you are changing.
   h. Have a member of the class record the number of students at each point of the scale.
   i. Repeat steps (b)–(h) for the other two statements.
   j. Reflect on what you have learned about the opinions and perspectives of others.
   k. Suggest questions that could be used to more closely probe reasons for your classmates' opinions. Share these probing questions with your class.

Results

1. Outline your score for each of the given statements.
2. Construct graphs showing the opinion scales for each statement and comment on any observed patterns.
3. Construct a PMI chart for each statement based on opinions and statements made by others in the class.

Discussion

1. Research two of the issues above. Construct a table with reasons for and against. Compare and discuss your table with others.
2. Select one of the statements (ensure it is different from the statements debated in step 2 of the Method) and organise a class debate.

Conclusion

Summarise your findings about opinions on ethical issues in science.

1.3 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 2, 5	Questions 3, 6, 8	Questions 4, 7, 9

Remember and understand

1. Identify each of the following statements as true or false. Justify your responses.
   a. A right is something we have if we can expect to be treated in a certain way, no matter what the consequences.
   b. Scientists can be influenced by goals, rights, needs and duties.
   c. The goals, rights and duties of scientific investigations become clearer when science is asked to provide us with answers about what we should do and how we should behave.
   d. Ethics are often involved in shaping our ideas about what is right and wrong.
   e. The type of research being funded by some private companies may be influenced more by its money-making potential than by its potential to reduce human suffering and improve quality of life.
   f. Nobel prize recipient Barry Marshall drank a container of *Helicobacter pylori* to infect himself to support his conviction that the actual cause of many stomach ulcers was bacterial rather than lifestyle.
2. Outline the five main principles of ethics.
3. Describe some ethical issues related to animal testing.
4. Outline some of the arguments against using genetically modified crops.

Apply and analyse

5. a. Laura is a member of the pre-musical performance squad. Shona would like to be a member of the squad.
   Think about this situation and the goals, rights, needs and duties that Laura and Shona each have, and then copy and complete the following table.

TABLE Identifying and specifying goals, rights, needs and duties

Person	Goals	Rights	Needs	Duties
Laura				
Shona				
Teacher in charge of casting				
Audience for the musical				
Rest of the cast				

   b. How people behave in any situation is largely determined by how they perceive the relative importance of their goals, rights, needs and duties.
      i. Describe how Shona may behave if she perceives that her goals and needs are of greater importance than those of others.
      ii. Contrast this with the behaviour you may expect if she perceives her goals as being less important than those of others.
      iii. How do you think Laura and Shona should behave towards each other?
6. Analyse each of the levels in Maslow's hierarchy of needs. How does this apply to your everyday life?
7. Drug trials were conducted in 2020 to test a vaccine against COVID-19. Provide recommendations on how integrity, justice, beneficence, non-maleficence and autonomy can be assured.

Evaluate and create

8. Comment on the following statement 'Scientific discoveries should belong to everyone'. Outline your opinions of this and write three paragraphs justifying your response.
9. We have had to face some very complex and difficult issues because of recent scientific and technological advances. Examples of issues being faced in Australia include:
   - compulsory immunisation of children
   - genetic manipulation of food crops and animals to optimise such things as their resistance to pests and their growth rate
   - irradiating food to maximise its shelf life
   - public funding of IVF technology
   - reducing irrigation to improve water quality of rivers
   - building a new nuclear reactor in Australia.

   Research one of the preceding issues and create a report summarising ethical considerations around this.

Fully worked solutions and sample responses are available on your digital formats.

1.4 Designing and conducting your own investigation

LEARNING INTENTION

At the end of this subtopic you will be able to design and conduct investigations with attention to variables, reports and scientific processes.

1.4.1 The scientific method

As a science student you are required to undertake scientific investigations. These investigations will not only help you understand scientific concepts, they can be a lot of fun! Scientists around the world all follow what is known as the **scientific method**. This allows scientists to examine each other's work and build on the scientific knowledge gained. An important aspect of science is being able to reproduce someone else's experiment. The more evidence a scientist has about a theory, the more accepted the theory will be.

The scientific method is summarised in **FIGURE 1.18**.

The skills you will develop in conducting scientific investigations include the following:
- questioning and predicting
- planning and conducting
- recording and processing
- analysing and evaluating
- communicating scientifically.

1.4.2 Begin with a plan

Whenever you take a trip away from home, you need to plan ahead and have some idea of where you are going. You need to know how you are going to get there, what you need to pack and have some idea of what you are going to do when you get there.

It's the same with an experimental investigation. Planning ahead increases your chances of success. It's easier if you can break an investigation down into steps.

scientific method a systematic approach to planning, undertaking and analysing research

FIGURE 1.19 The scientific method

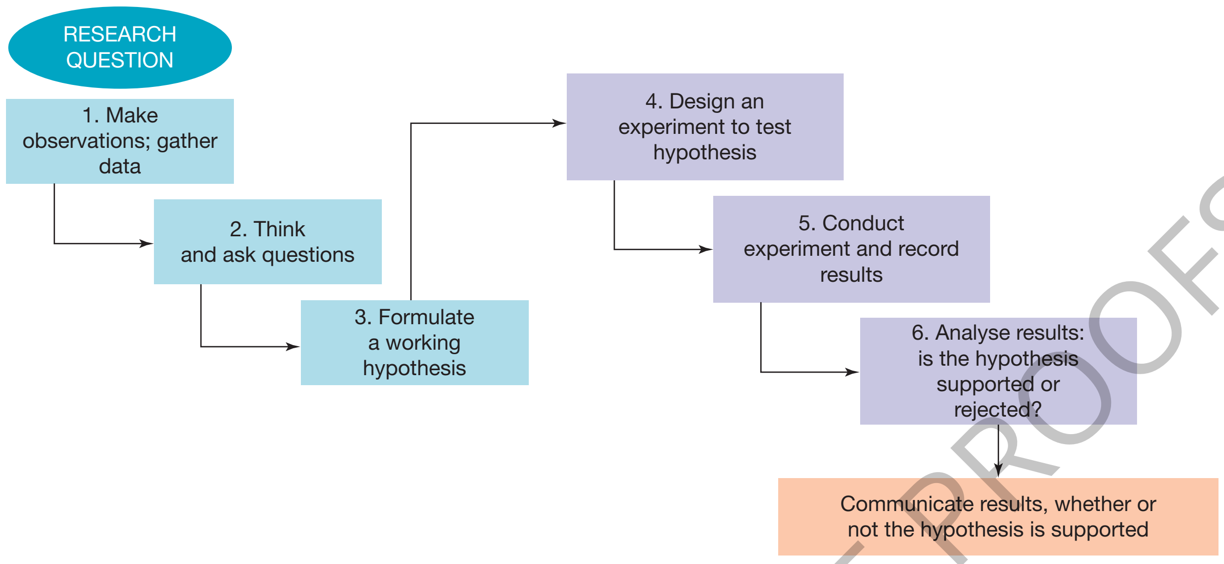


FIGURE 1.20 What sorts of questions do you ask yourself to decide whether you should take on new learning?

Designing your own investigation requires a great appreciation of your learning, and requires you to be creative, organised and be able to persevere and adapt when things don't work the way you expect.

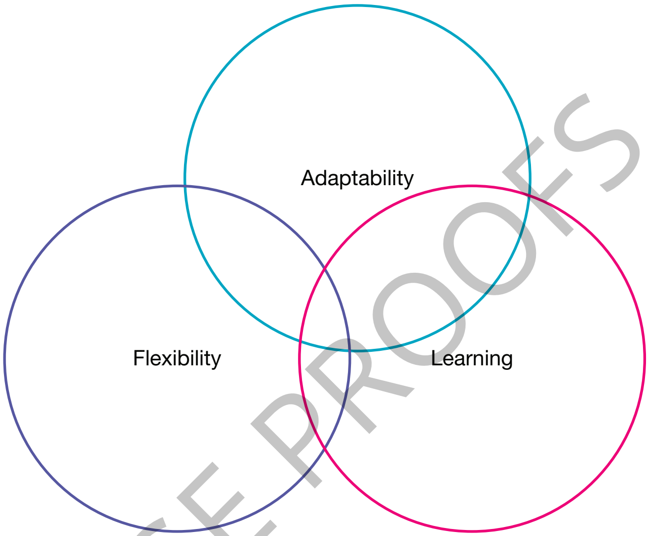
Part of being a scientist is through the action of refinement — there are no failures in science, but, instead, lessons that allow you to adjust your hypothesis and try something new. That is all part of the excitement of scientific investigation.

The four Rs

In order to plan an investigation, it helps to consider the four Rs: resilience, reflectiveness, responsibility and resourcefulness.

- **Resilience** is about believing in yourself and having the ability to tolerate sometimes feeling a little uncomfortable. As learning is an emotional business, your ability to tolerate emotions is important. Learning is not always fast and smooth; there can be frustrating flat spots, exhilarating highs and upsetting setbacks. Resilience helps you to stick with it and recover from any disappointments. It is important in learning to help you tolerate your emotional seesaw.
- **Reflectiveness** is being self-aware and mindful of what could be and what has been. It involves being open-minded and sometimes standing back and looking at the big picture; asking yourself if your own assumptions are getting in the way of the truth.
- **Responsibility** is being able to manage yourself and your learning. It's about monitoring your progress and thinking about other options and different perspectives.
- **Resourcefulness** is knowing what tools you have and when to use them. It's about taking responsible risks and using a range of appropriate learning tools and strategies.

FIGURE 1.21 Resilience involves many different aspects



1.4.3 Keeping records

A **logbook** is an essential part of a long scientific investigation. It provides you with a complete record of your investigation, from the time you begin to search for a topic. Your logbook will make the task of writing your report very much easier.

A logbook is just like a diary. Make an entry whenever you spend time on your investigation. Each entry should be clearly dated. It's likely that the first entry will be a mind map or list of possible topics. Other entries might include:

- notes on background research conducted in the library. Include all the details you will need for the bibliography of your report (see section 1.4.10)
- a record of the people that you asked for advice (including your teacher), and their suggestions
- diagrams of equipment, and other evidence that you have planned your experiments carefully
- all of your 'raw' results, in table form where appropriate
- an outline of any problems encountered and how you solved them
- first drafts of your reports, including your thoughts about your conclusions

An online logbook

An exercise book can be used as a logbook, but there are several advantages in maintaining your logbook online in the form of a **blog** or in a program such as OneNote. If you choose to use a blog to record your investigation, there are many sites that will allow you to set up a free blog. Your teacher might be able to provide some suggestions. Once you set up a blog, every entry you make will be

resilience the ability to tolerate feeling a little uncomfortable sometimes

reflectiveness being self-aware, open-minded and sometimes standing back and looking at the big picture

responsibility being able to manage yourself and your learning

resourcefulness taking responsible risks and using a range of appropriate learning tools and strategies

logbook a complete record of an investigation from the time a search for a topic is started

blog a personal website or web page where an individual can upload documents, diagrams, photos and short videos dated automatically. You can upload documents, diagrams, photos and short videos. You can also add links to other sites and invite friends, family and teachers to post comments about your progress.

There are some precautions that you should take if you decide to use a blog as a logbook.

- Limit your posts to those related to your science investigation. Don't use your logbook blog for social networking.
- Do not include your address or phone number.
- If your blog is on the internet (rather than a school intranet):
  - do not post any photos of yourself in school uniform or any other clothing that will identify where you go to school
  - do not include your full name, address, phone number or the name of your school in the blog. Use only your first name or a nickname
  - use privacy settings or use a password to ensure that only trusted school friends, family and your teacher have access to the blog.

FIGURE 1.22 A blog used as a logbook for a student research investigation.

on Resources

eWorkbook Setting up a logbook (ewbk-6543)

1.4.4 Finding a topic

Your investigation is much more likely to be of high quality if you choose a topic that you will enjoy working on. These steps might help you choose a good topic.

1. Think about your interests and hobbies. They might give you some ideas about investigation topics.
2. Make a list of your ideas.
3. Brainstorm ideas with a partner or in a small group. You might find that exchanging ideas with others is very helpful.
4. Find out what other students have investigated in the past. Although you will not want to cover exactly the same topics, investigations performed by others might help you to think of other ideas.
5. Do a quick search in the library or at home for books or newspaper articles about topics that interest you. Search the internet. You might also find articles of interest in magazines or journals. You could use a table (such as table 1.2) to organise your ideas.

FIGURE 1.23 When designing a research question it helps to **(a)** think about your interests, **(b)** think about your hobbies and **(c)** brainstorm your ideas with others.

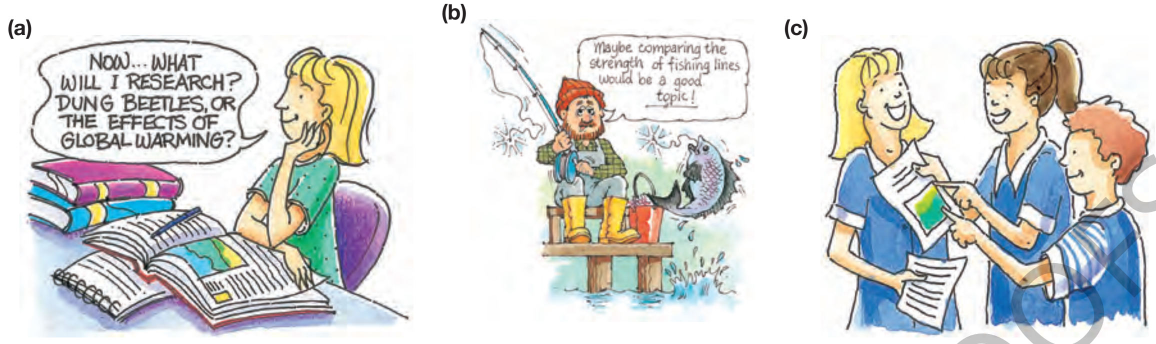


TABLE 1.2 A record of topic area and relevant resources

Topic area	Name of book, magazine, website, etc.	Chapter or article	Topic ideas

From observations to ideas

Many ideas for scientific investigations start with a simple observation. Some well-known investigations and inventions from the past started that way.

Even discoveries that were made by accident (such as the discovery of penicillin by Fleming) would not have been made without observation skills.

Other important 'ingredients' in these discoveries are curiosity and the ability to ask questions and form ideas that can be tested by experiment and further observation.

DISCUSSION

Write a list of things you are curious about (you may look around the room to help you) — this may be something you observe around you or even something related to one of your hobbies. Discuss this with the class and see if you can come up with a list of ideas for an investigation.

1.4.5 Formulating a question

Once you have decided on your topic, you need to determine exactly what you want to investigate. It is better to start with a simple, very specific question than a complicated or broad question.

For example, the topic 'basketball' is very broad. Many simple questions could be asked about basketball that you could use as a basis of an i nvestigation.

- What size basketball bounces the highest?
- What angle should you throw the ball from the free throw line to shoot a goal?
- What surface of basketball court allows you to run the fastest?

Your question needs to be realistic and testable. In defining the question, you need to consider whether:

- you can obtain the background information that you need
- the equipment that you need is available
- the investigation can be completed in the time you have available
- the question is safe to investigate

In science, it is important that you continually revise and refine your investigation question. You may find that your question is too broad and doesn't provide clear observations or findings that allow you to draw conclusions. You may find that your question cannot be answered through investigation or observations that are available to you. You might even find that when designing your investigation, you do not have the time and resources to answer your investigation question. It is important that as you formulate questions, you keep track of the refinement and revision of this question. It is often helpful to record a note to yourself about WHY you altered your question of investigation.

FIGURE 1.24 What questions might you ask about the topic of basketball?

1.4.6 Creating an aim and hypothesis using variables

What are variables?

In every investigation, there are different variables. Variables are observations or measurements that can change during an experiment. You should only change one variable at a time in an experiment.

When determining your aim and hypothesis, you need to be able to identify your independent and dependent variable.

- The **independent variable** is the one which is deliberately manipulated by an investigator during an experiment.
- The **dependent variable** is the one that is measured or observed by the investigator during an experiment. It is a variable that may change when the independent variable is changed.

For example, if you were performing an experiment to find out which brand of fertiliser was best for growing a particular plant, the independent variable would be the brand of fertiliser. The dependent variable would be the heights of the plants after a chosen number of days.

A third type of variable, known as **controlled variables**, are also important in designing investigations. These will be explored in section 1.4.7.

independent variable a variable that is deliberately changed during an experiment

dependent variable a variable that you measure that is influenced by changes to the independent variable

controlled variable the conditions that must be kept the same throughout an experiment

Aim

Your investigation should have a clear and realistic aim. Your aim should be very specific and clear. The aim of an investigation is its purpose, or the reason for doing it.

When writing an aim, you should always link together the dependent and independent variables. Some examples of aims are as follows.

- To determine how the size of wheels affects the speed of a toy car
- To compare the effect of different fertilisers on the growth of pea plants
- To find out whether different coloured lights affect the growth of algae in an aquarium
- To determine which metal is the most reactive in hydrochloric acid

Hypothesis

A hypothesis is a statement that is a prediction for your investigation. Your hypothesis should relate to your aim and should be testable with an experimental investigation.

The results of your investigation will either support (agree with) or not support (disagree with) the hypothesis. A hypothesis cannot be proven correct, but rather have evidence that further supports the statement made.

There are many ways to formulate a hypothesis. It is important that it is a statement and not a question.

One way to write a hypothesis is through the IF…THEN… format. Some examples of hypotheses (based on the aims above) are:
- IF the wheels of a toy car are increased in size, THEN then the speed of the car will increase
- IF the fertiliser with the most nutrients is used, THEN the pea plants will grow at a faster rate
- IF different lights are shone on algae in an aquarium THEN algae under the red light will have the highest growth rate
- IF different metals are placed in hydrochloric acid THEN group I metals will be the most reactive.

1.4.7 Designing an experiment

In order to complete a successful investigation, you need to make sure that your experiments are well designed. Once you've decided exactly what you are going to investigate, you need to be aware of:
- which variables need to be controlled and which variables can be changed
- whether a control is necessary
- what observations and measurements you will make and what equipment you will need to make them
- the importance of repeating experiments (replication) to make your results more reliable
- how you will record and **analyse** your data.

A poorly designed investigation is likely to produce a conclusion that is not valid.

analyse examine methodically and in detail to answer a question or solve a problem

fair testing a method for determining an answer to a problem without favouring any particular outcome

control an experimental set-up in which the independent variable is not applied

valid sound or true experiment that can be supported by other scientific investigations

replication repeating of an experiment to make sure you have collected reliable data

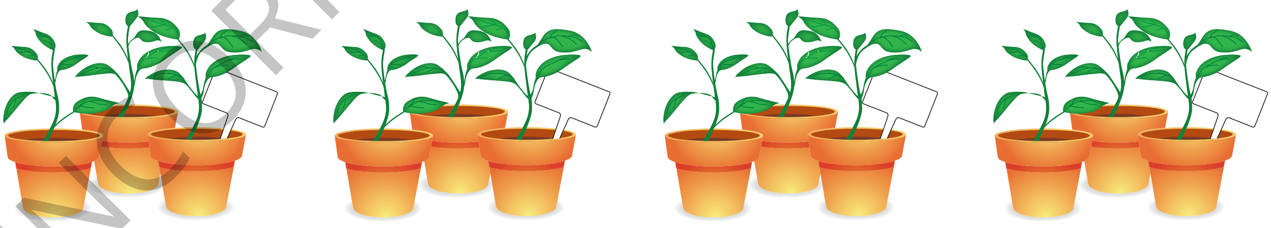
reliable data data that can be replicated in different circumstances but same conditions

Controlling variables

When you are testing the effect of an independent variable on a dependent variable, all other variables should be kept constant. Such variables are called controlled variables. For example, in the fertiliser experiment, the type of plant, amount of water provided to each plant, soil type, amount of light, temperature and pot size are all controlled variables. The process of controlling variables is also known as **fair testing**.

The need for a control

Some experiments require a **control**. A control is needed in the fertiliser experiment to ensure that the result is due to the fertilisers and not something else. The control in this experiment would be a pot of plants to which no fertiliser was added. All other variables would be the same as for the other three pots.



Valid experiments

A **valid** experiment measures what it actually sets out to measure. If your aim was to find out whether watering plants with sea water affects their growth rate, comparing the number of radish seeds that germinate after one week when watered with tap water or sea water would not be a valid method because it does not actually measure growth rate. It tests the effect of sea water on seed germination.

Reliable experiments

Replication is the repeating of an experiment to make sure you have collected **reliable data**. In the case of the fertiliser experiment, a more reliable result could be obtained by setting up multiple pots for each brand of or having multiple seedlings in eah pot. An average result for each brand or the control could then be calculated.

A reliable experiment provides consistent results when repeated, even if it is repeated on different days and under slightly different conditions; for example, in a different room or with a different researcher collecting the data. Replication increases the reliability of an experiment. This can involve simply doing the same experiment a few times, or having different groups repeat the same experiment and pooling the data gathered by each group when writing the report.

on Resources

eWorkbook Variables and controls (ewbk-6545)

Video eLesson Is this a good experiment? (eles-2630)

1.4.8 Getting approval

You should now be ready to write a plan for your investigation. You should not commence any experiments until your plan has been approved by your science teacher. You plan should include the following information.

1. **Title**
   The likely title — you may decide to change it before your work is completed. Usually, your title is your research question. The title should be in the form of a question; for example, How does watering grass seeds with a detergent solution affect their growth?
2. **The problem**
   A statement of the question that you intend to answer. Include a hypothesis. A hypothesis is an educated guess about the outcome of your experiments. It is usually based on observations and able to be tested by further observations or measurements.
3. **Outline of your experiments**
   Outline how you intend to go about answering the question. This should briefly outline the experiments that you intend to conduct.
4. **Equipment**
   List here any equipment that you think will be needed for your experiments.
5. **Resources**
   List here the sources of information that you have already used and those that you intend to use. This list should include library resources, organisations and people.

FIGURE 1.25 Write out a plan for your investigation.

Safety

When getting approval from your teacher, it is important to show that you have considered safety (and ethics, which was covered earlier in the topic).

Some general safety precautions that will help to ensure you and others are not harmed include:

- Wearing protective clothing. This might include laboratory coat, safety glasses and gloves.
- Being aware of the position of safety equipment, such as fire blanket, fire extinguisher, safety shower and eye wash.
- Reading labels carefully to confirm contents and concentration of chemicals or pathogenic agents.

FIGURE 1.26 Safety equipment including safety glasses, gloves and lab coats are vital in various experiments.

- Correct disposal of equipment and chemicals, including damaged equipment (i.e. broken glassware) and cleaning and packing up of equipment.
- Conducting an investigation as outlined in your approved plan. Don't vary your plan without approval from your teacher.

Often, hazards are addressed through a **risk assessment**, which allows for the identification of hazardous chemicals and equipment, what risks are involved and what procedures need to be followed to work safely with these. You may be asked to create a risk assessment by your teacher as part of the submission of your plan.

1.4.9 Conducting investigations and gathering data

Once your plan has been approved by your teacher, you may begin your experiments.

Details of how you conducted your experiments should be recorded in your logbook. All observations and measurements should be recorded. Use tables where possible to record your data.

Where appropriate, measurements should be repeated and an average value determined. All measurements — not just the averages — should be recorded in your logbook.

Photographs should be taken if appropriate.

You might need to change your experiments if you get results you don't expect. Any major changes should be checked with your teacher.

FIGURE 1.27 All observations and measurements should be recorded.

Precision and accuracy

As you plan and carry out your investigation you need to ensure that the data you collect is **precise** and **accurate**. Choosing the most appropriate instruments to make your measurements is important.

- Precision refers to how close multiple measurements of the same investigation are to each other.
- Accuracy refers to how close an experimental measurement is to a known value.

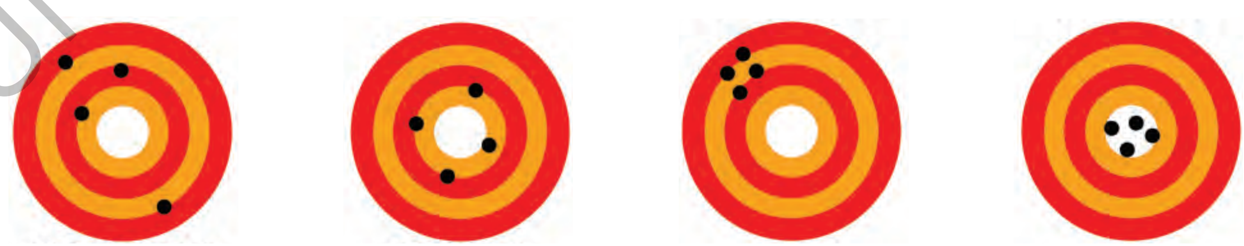
If an archer is precise, their arrows hit close to one another. If an archer is accurate, their arrows hit close to the target.

risk assessment a procedure that identifies the potential hazards of an experiment and gives protective measures to minimise the risk

precise multiple measurements of the same investigation being close to each other

accurate an experimental measurement that is close to a known value

FIGURE 1.28 Comparing accuracy and precision

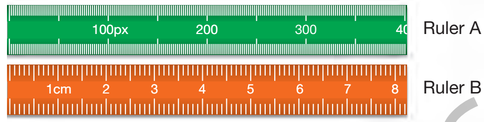


Not accurate not precise | Accurate not precise | Not accurate precise | Accurate and precise

Choosing equipment for precision

Choosing the correct piece of equipment is critical to ensure that your results are precise. Your bathroom scales and the electronic scales in a science laboratory both measure mass, but the laboratory scales are more precise. Your school might have different sets of scales that measure to one or two decimal places. Scales that measure to two decimal places are more precise. High precision scales are needed for some of the senior chemistry experiments.

FIGURE 1.29 Which ruler is more precise: ruler A or ruler B?



For measuring instruments with a scale, such as thermometers, rulers (as shown in figure 1.32) and measuring cylinders, the graduations (lines) on the scale give an indication of the precision of the instrument. Generally, an instrument with smaller gradations is more precise.

When liquids are placed in a vessel, the surface of the liquid is often curved (as shown in figure 1.33). This curved surface of a column of liquid is called a **meniscus**. Measurements must be recorded from the bottom of this meniscus.

FIGURE 1.30 You always should measuring liquids from the base of the meniscus

Ensuring equipment is accurate

Measurements can be very precise, but incorrect. Every so often current affairs TV programs bring attention to service stations that overcharge customers for petrol by having faulty petrol pumps that give inaccurate readings of the amount of petrol delivered by the pump. For each litre of petrol pumped the machine might give a reading of 1.1 L and the customer is charged accordingly. The machine is quite precise, but not accurate.

FIGURE 1.31 A pH meter needs to be calibrated regularly to ensure it gives accurate readings.

Some measuring instruments require **calibration** to ensure that they provide accurate measurements. The calibration might be part of the manufacturing process, or it may need to be carried out by the user regularly. A pH meter is a device that needs to be calibrated regularly. pH is a measure of the acidity of a substance. You can measure pH with a universal indicator. For a more precise reading a pH meter can be used. It is a device that is placed in the solution and it gives a reading of the pH to one or two decimal places. Over time it can lose its calibration and give inaccurate readings. A reading of 6.25 might be displayed when the solution actually has a pH of 5.38. To calibrate the pH meter you place it in solutions of known pH and adjust the device until it reads the correct values for these solutions. You can then use the meter to measure the pH of a solution with an unknown concentration.

Graphing variables

Many different types of data can be collected in scientific experiments. Data is often presented in tables or as graphs.

Tables

Tables can be used to record data to help separate and organise your information. All tables should:

- have a heading
- display the data clearly, with the independent variable in the first column and the dependent variable in later columns

meniscus the curve seen at the top of a liquid in response to its container

calibration the process whereby a measuring instrument is restored to accuracy

- include units in the column headings and not with every data point
- be designed to be easy to read.

TABLE 1.3 The effect of different brands of fertilisers on the height of seedlings.

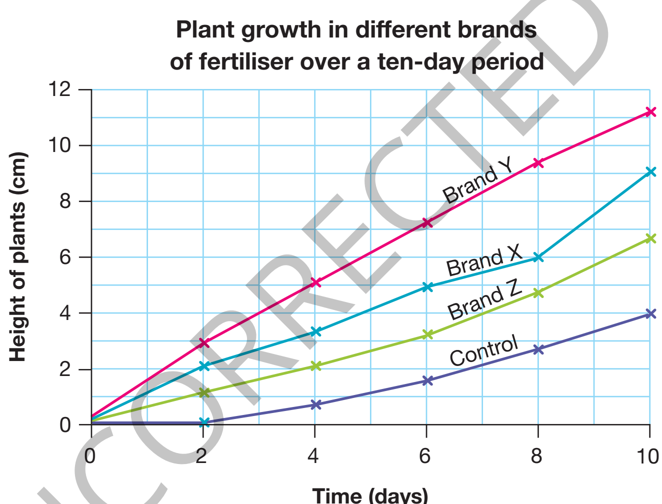
Fertiliser	Day 2 Height of seedling (cm)	Day 4 Height of seedling (cm)	Day 6 Height of seedling (cm)	Day 8 Height of seedling (cm)	Day 10 Height of seedling (cm)
Brand X	2	3	5	6	9
Brand Y	3	5	7	9	11
Brand Z	1	2	3	5	7
Control	0	0.6	1.8	2.5	4

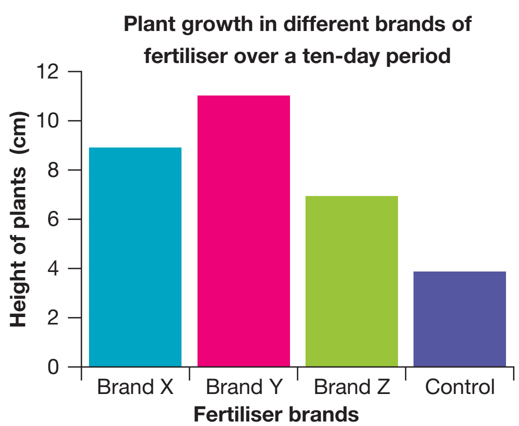
Graphs

Graphs can help you see patterns and trends in your data. Once your data is recorded in a table, you need to work out the best graph to choose. This is often affected by the type of data you have (is your data qualitative or quantitative).

If you use a graph to show your results, you would normally graph the independent variable (the one you changed) on the *x*-axis, and the dependent variable (the one you measured) on the *y*-axis. When the dependent variable changes with time, you can graph time on the *x*-axis and the dependent variable on the *y*-axis. For example, in the fertiliser experiment, two types of graphs could be used, a line graph or a column graph (bar chart).

FIGURE 1.32 Some examples of graphs used in a fertiliser experiment





Different types of graphs are appropriate in different circumstances.

- *Scatterplots* require both sets of data to be numerical. Each dot represents one observation. A scatterplot can easily show trends between data sets, and correlations can be seen. A line of best fit may be added to show the overall trend in the data.
- *Bar/column* graphs can be used when one piece of data is qualitative and the other is quantitative. The bars are separated from each other. The horizontal axis has no scale because it simply shows categories. The vertical axis has a scale showing the units of measurement.
- *Histograms* are a special kind of bar graph that show continuous categories, and are often used when examining frequency. The bars are not separated.
- *Pie charts* and *divided bar charts* are used to show frequencies or portions of a whole. This includes percentages or fractions.

Resources

eWorkbook Organising and evaluating results (ewbk-6547)

Interactivity Sector graphs or pie graphs (int-4061)

1.4.10 Writing your report

You can begin writing your report as soon as you have planned your investigation, but it cannot be completed until your observations are complete. Your report should be typed or neatly written on A4 paper and presented in a folder. It should begin with a table of contents, and the pages should be numbered. Your report should include the following headings (unless they are inappropriate for your investigation).

Scientific report structure

Abstract

The abstract provides the reader with a brief summary of your whole investigation. Even though this appears at the beginning of your report, it is best not to write it until after you have completed the rest of your report.

Introduction

Present all relevant background information. Include a statement of the problem that you are investigating, saying why it is relevant or important. You could also explain why you became interested in the topic.

Aim

State the purpose of your investigation; that is, what you are trying to find out. Include the hypothesis.

Materials and methods

Describe in detail how you did your experiments. Begin with a list or description of equipment that you used. You could also include photographs of your equipment if appropriate. The method description must be detailed enough to allow somebody else to repeat your experiments. It should also convince the reader that your investigation is well controlled. Labelled diagrams can be used to make your description clear. Using a step-by-step outline makes your method easier to follow.

Results

Observations and measurements (often referred to as data) are presented here. Data should, wherever possible, be presented in table form for ease of reading. Graphs can be used to help you and the reader interpret data. Each table and graph should have a title. Make sure you use the most appropriate type of graph for your data.

Your results should allow for trends and patterns to be seen, and for any outliers (unusual results) to be observed.

When showing your results, you should consider the mean (average), median (middle values) and range to help best show your data, and which type of data will best reflect your findings.

Discussion

Discuss your results here. Begin with a statement of what your results indicate about the answer to your question. Explain how your results might be useful. Any weaknesses in your design or difficulties in measuring could be outlined here. Explain how you could have improved your experiments. What further experiments are suggested by your results?

You should also outline how error has affected your results. Errors may include:

- **Human error** — mistakes made by individuals. These may be a major miscalculation in your results or a significant misreading or misinterpretation of results (for example, the indicator turned green and you accidentally note down it was red). Human errors impact the reliability of your data, as it is very difficult for similar results to be obtained by other individuals if you made a mistake and drew incorrect conclusions based off this.

human error individual mistakes made in investigations

- **Systematic error** — errors that affect accuracy (how close a measurement is to the actual value). This is often due to equipment error; for example, a 30 cm ruler is actually only 29 cm, so all measurements are wrong using this ruler.
- **Random error** — chance errors that may occur that affect how close results are to each other (precision). These are often mitigated by repeating investigations and taking an average. These are normal errors that occur; for example, slight differences in reaction time when recording the time taken for a reaction to occur.

As well as the above , you should also address any uncertainties in the data that you obtain, and factors that may influence the accuracy and precision of your data and findings.

In your discussion, you may also link your information to similar findings or other scientific reports. In using secondary data, you should ensure that this is valid, and from a source that is reliable, such as in peer-reviewed scientific journals.

You may use this secondary scientific evidence alongside your primary data that you gathered to help support your findings. Remember, there may be multiple explanations for your data, so secondary sources can assist you in formulating conclusions.

Conclusion

This is a brief statement of what you found out. It is a good idea to read your aim again before you write your conclusion. Your conclusion should also state whether your hypothesis was supported. You should not be disappointed if it is not supported. In fact, some scientists deliberately set out to reject hypotheses!

Bibliography

Make a list of books, other printed or audio-visual material and websites to which you have referred. The list should include enough detail to allow the source of information to be easily found by the reader. Arrange the sources in alphabetical order.

The way a resource is listed depends on whether it is a book, magazine (or journal) or website. For each resource, list the following information in the order shown:
- author(s), if known (book, magazine or website)
- title of book or article, or name of website
- volume number or issue (magazine)
- URL (website) and the date you accessed the web page
- publisher (book or magazine), if not in title
- place of publication, if given (book)
- year of publication (book, magazine or website)
- chapter or pages used (book).

Some examples of different sources are listed below:
- Taylor, N, Stubbs A., Stokes, R. (2020) *Jacaranda Chemistry 2 VCE Units 3 & 4*. 2nd edition. Milton: John Wiley & Sons.
- Gregg, J, (2014), 'How Smart are Dolphins?' *Focus Science and Technology*, Issue 264, February 2014, BBC, pages 52–57
- Australian Marine Wildlife Research & Rescue Organisation, http://www.amwrro.org.au, 2014.

Acknowledgements

List the people and organisations who gave you help or advice. You should state how each person or organisation assisted you.

on Resources

eWorkbook Components of a practical report (ewbk-6549)

systematic error an error (often due to equipment) that affects the accuracy of results

random error an error that affects the precision of results

1.4 Exercise

learnon

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3, 5, 9	Questions 2, 4, 6, 11	Questions 7, 8, 10

Remember and understand

1. Construct a flowchart to show the steps that you need to take before beginning your experiments.
2. What is the advantage of repeating an experiment several times?
3. Describe the difference between an independent and a dependent variable. Provide an example of each.
4. Outline an example of the use of a control in an experiment.
5. In which section of your report do you describe possible improvements to your experiments?

Apply and analyse

6. For each problem described, identify the independent and dependent variable and three other variables that would need to be controlled.
   a. Josie wanted to find out whether the adding salt to a pot of water causes it to boil faster.
   b. Charlotte would like to investigate if plants watered with pure water grew faster than those watered with lemonade.
   c. Jayden is testing the hypothesis that wearing a swimming cap makes you swim faster.
   d. Shinji is testing the myth that classical music played to a baby in the womb results in them having a higher IQ.
   e. Nikita has heard that most people shrink slightly (in height) throughout the day and stretch out at night. She would like to know whether this is true.
7. Discuss the advantages and disadvantages of using a blog as a logbook for your investigation.
8. Why is it better to write the abstract of a scientific report last, even though it appears at the beginning?
9. Describe why it is important to write a risk assessment before you conduct an investigation.

Evaluate and create

10. You wish to conduct a practical investigation to determine how fast 100 mL water takes to boil in different sized containers.
    a. Write a research question for this topic.
    b. Write an aim and hypothesis for this investigation.
    c. Summarise the materials you would use in this investigation.
    d. Write a method summarising how you will explore this topic.
11. A student explored the growth of a plant when watered with different solutions and obtained the following results.

TABLE The effect of watering plants with different types of solutions on plant growth.

Watering solution	Day 1 Growth of plant (cm)	Day 2 Growth of plant (cm)	Day 3 Growth of plant (cm)
Water	2.1	5.4	7.1
Lemonade	3.2	6.7	9.4
Soda water	2.5	5.9	8.2

Show this information in a graph and analyse the data obtained.

Fully worked solutions and sample responses are available on your digital formats.

1.5 SkillBuilder — Controlled, dependent and independent variables

1.5.1 Why do we need to manage variables in an investigation?

In an investigation, it is important to only change one of the variables at a time and then observe what that change brings about in the other variables.

Select your learnON format to access:
- an overview of the skill and its application in science (Tell me)
- a video and a step-by-step process to explain the skill (Show me)
- an activity and interactivity for you to practise the skill (Let me do it)
- questions to consolidate your understanding of the skill.

on Resources

eWorkbook	SkillBuilder — Controlled, dependent and independent variables (ewbk-6551)
Video eLesson	Controlled, dependent and independent variables (eles-4225)
Interactivity	Controlled, dependent and independent variables (int-8154)

1.6 SkillBuilder — Writing an aim and forming a hypothesis

1.6.1 Why do we need to write aims and form hypotheses?

In science, we conduct investigations to draw conclusions and gather data and results. Every investigation requires an aim — a short statement of what we are trying to achieve. Alongside an aim, the ability to formulate predictions is important in science. This is performed through the use of a hypothesis. Being able to write aims and hypotheses are vital skills for any scientist.

Select your learnON format to access:
- an overview of the skill and its application in science (Tell me)
- a video and a step-by-step process to explain the skill (Show me)
- an activity and interactivity for you to practise the skill (Let me do it)
- questions to consolidate your understanding of the skill.

on Resources

eWorkbook	SkillBuilder — Writing an aim and forming a hypothesis (ewbk-6553)
Video eLesson	Writing an aim and forming a hypothesis (eles-4226)
Interactivity	Writing an aim and forming a hypothesis (int-8155)

1.7 SkillBuilder — Measuring and reading scales (including parallax error)

1.7.1 Why do we need to measure and read scales?

When conducting experiments, it is critical that measurements and data are recorded accurately. Whether measuring volume or temperature, or interpreting alternate scales, it is important that they are recorded accurately.

In science, a scale or set of numbered markings generally accompanies each measuring device. For example, your ruler measures length, and its scale has markings enabling you to measure with an accuracy of 0.1 cm. When reading a scale, it is important to determine what each of the markings on the scale represents.

A small measuring cylinder can provide a reasonably precise measurement of a volume of water but, if it is not read at eye level, the measurement may not be accurate. Measurements should always be made with your eye in line with the reading you are taking. When scales are read from a different angle, the reading is not accurate. This type of reading error is called **parallax error**.

Select your learnON format to access:

- an overview of the skill and its application in science (Tell me)
- a video and a step-by-step process to explain the skill (Show me)
- an activity and interactivity for you to practise the skill (Let me do it)
- questions to consolidate your understanding of the skill.

on Resources

eWorkbook	SkillBuilder — Measuring and reading scales (ewbk-6555)
Video eLesson	Measuring and reading scales (eles-4227)
Interactivity	Measuring and reading scales (int-8156)

1.8 SkillBuilder — Creating a simple column or bar graph

1.8.1 What is a column or bar graph?

Column graphs show information or data in columns. In a bar graph, the bars are drawn horizontally and in column graphs, they are drawn vertically. They can be hand drawn or constructed using computer spreadsheets.

Select your learnON format to access:

- an overview of the skill and its application in science (Tell me)
- a video and a step-by-step process to explain the skill (Show me)
- an activity and interactivity for you to practise the skill (Let me do it)
- questions to consolidate your understanding of the skill.

parallax error the effect where the position or direction of an object appears to differ when viewed from a different position

on Resources

eWorkbook	SkillBuilder — Creating a simple column or bar graph (ewbk-6557)
Video eLesson	Creating a simple column or bar graph (eles-4228)
Interactivities	Creating a simple column or bar graph 1 (int-4058)
	Creating a simple column or bar graph 2 (int-4059)

1.9 SkillBuilder — Drawing a line graph

1.9.1 What is a line graph?

A line graph displays information as a series of points on a graph that are joined to form a line. Line graphs are very useful to show change over time. They can show a single set of data, or they can show multiple sets, which enables us to compare similarities and differences between two sets of data at a glance.

Select your learnON format to access:

- an overview of the skill and its application in science (Tell me)
- a video and a step-by-step process to explain the skill (Show me)
- an activity and interactivity for you to practise the skill (Let me do it)
- questions to consolidate your understanding of the skill.

on Resources

eWorkbook	SkillBuilder — Drawing a line graph (ewbk-6559)
Video eLesson	Drawing a line graph (eles-1635)
Interactivity	Drawing a line graph (int-3131)

1.10 Sample scientific investigation

LEARNING INTENTION

At the end of this subtopic you will be able to design your own investigation using a sample investigation as an example.

1.10.1 Investigating muddy water

Sean, a Year 10 student, conducted an experimental investigation to compare the turbidity (cloudiness) of water in the following three locations:

- a creek near his school
- a creek near his home
- a river near his home

His search for information in the library revealed that the cloudiness was caused by particles of soil (and sometimes pollution) suspended in the water. Sean chose his topic because he was interested in the environment. He felt that clean water was the right of all living things. His research and background knowledge led him to form the hypothesis that 'the clearest water will be in the river'.

Sean took water samples from each of the three locations on four days. He found a method of measuring turbidity from a library book. It involved adding a chemical called potash alum to a sample of water in a jar. The potash alum makes the particles of suspended soil clump together and fall to the bottom of the jar. A layer of mud is formed. The height of the mud at the bottom is then measured.

A summary of Sean's method, including a list of materials and equipment required, is given above. You will notice that Sean used a fourth sample. It was needed as a control and contained distilled water. This was to ensure that there was nothing in the pure water to cause a layer at the bottom of the jar when the potash alum was added. His results are in table 1.4.

SEAN'S INVESTIGATION

Materials

- 4 large jars or bottles with lids for collecting water samples (capacity of about 1 L each)
- 4 identical jam jars with lids, labelled 1, 2, 3 and 4
- metal teaspoon (not plastic, in case it breaks)
- potash alum (potassium aluminium sulfate)
- 4 water samples from different locations
- ruler with 1-millimetre graduations
- 100 mL measuring cylinder
- permanent marker

Method

1. Water samples (about 1 litre each) were collected from a specific part of the creeks and river on the same day.
2. Each of three clean jars was filled to the same level with the water samples — a labelled jar for each location. A fourth labelled jar was filled to the same level with distilled water.
3. One level teaspoon of potash alum was added to each jar. Lids were put on the jars and the jars were shaken.
4. The jars were left for 30 minutes to allow the particles to settle.
5. The height of the layer of mud on the bottom of each jar was measured and recorded.
6. The jars were emptied and washed and the experiment was repeated three more times.
7. Water samples were collected from the same locations on three other days over a ten-day period and the entire experiment was repeated three more times.

TABLE 1.4 Results table measuring the levels of mud in water samples from three different areas

Water sample	Height of mud (mm)															
	Day 1				Day 2				Day 3				Day 4			
	Test			Average	Test			Average	Test			Average	Test			Average
	1	2	3		1	2	3		1	2	3		1	2	3	
1. Home creek	3.5	4.0	5.0	4.2	5.0	4.5	5.0	4.8	4.5	5.0	4.5	4.3	5.0	4.5	4.0	4.5
2. School creek	2.5	2.0	2.0	2.2	3.0	2.5	2.5	2.7	2.0	2.5	2.5	2.3	2.0	2.0	2.5	2.2
3. Barnes River	1.0	0.5	0	0.5	2.0	1.0	1.5	1.5	0.5	1.0	0.5	0.7	0.5	0.5	0.5	0.5
4. Distilled water	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

1.10.2 Analysing the data

Sometimes it is necessary to refine the raw data (the data initially collected), presenting them in a different way. Sean was planning to use his average measurements to make a column graph. He decided to simplify his table so that it was easier to construct the column graph. The simplified table and column graph make it easier for others to read the results, and easier for Sean to see patterns and draw conclusions.

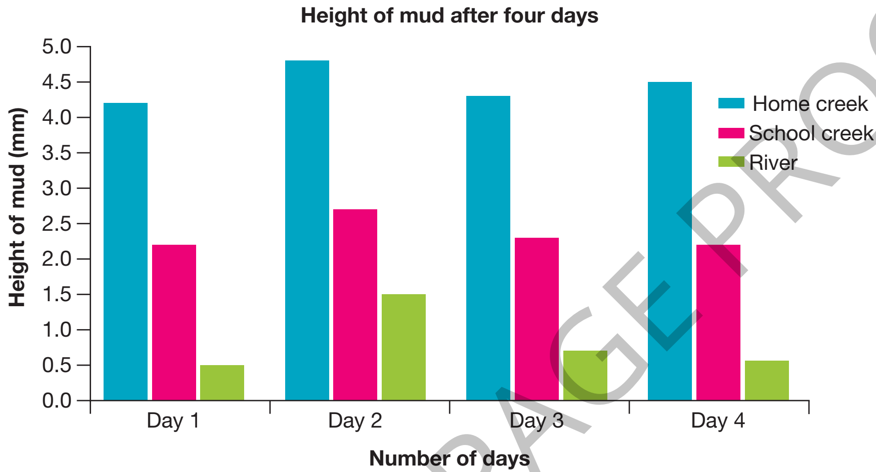
TABLE 1.5 Average heights of mud in water from three different areas

Water sample	Average height of mud (mm)			
	Day 1	Day 2	Day 3	Day 4
1. Home creek	4.2	4.8	4.3	4.5
2. School creek	2.2	2.7	2.3	2.2
3. Barnes River	0.5	1.5	0.7	0.5

1.10.3 Being critical

Sean was pleased with his results and was able to draw conclusions. In the discussion section of his report, he suggested that further studies be done. The turbidity was affected by weather conditions and the sampling needed to be done over a longer period, and in different weather conditions. Sean had recorded weather details on each day that he sampled water and was able to explain the very high mud level in the river on day 2. It is almost always possible to suggest improvements to your experiments.

FIGURE 1.33 Sean's graph makes it easier to see patterns and draw conclusions.



1.10.4 Drawing conclusions

Sean's hypothesis, that the clearest water would be in the river, was supported. His conclusion was written in point form.

1. The home creek has the muddiest water, with sample values ranging from heights of 4.2 to 4.8 mm of mud per 200 mL of water. The school creek has moderate amounts of mud compared to the other two samples. Sample values ranged from 2.2 to 2.7 mm of mud per 200 mL of water. The river water is the clearest, with sample values of 0.5 to 1.5 mm of mud per 200 mL of water.
2. Weather conditions can alter the amount of mud in water bodies by either adding run-off from drains or stirring up the water. This was particularly noticeable in the samples taken from the river site on day 2, which followed a period of rain.

FIGURE 1.34 Chemical waste running into a river. How might you test for such materials in a water sample from this site?

on Resources

eWorkbooks Scientific investigation examples (ewbk-6561)

Drawing conclusions (ewbk-6563)

1.10 Exercise

learnON

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3	Questions 2, 5	Questions 4, 6

Remember and understand

1. For Sean's experiment, identify:
   a. the independent variable
   b. the dependent variable
   c. the variables he controlled.

Apply and analyse

2. Explain why a sample of distilled water was included in Sean's experiment.
3. Explain why Sean repeated the experiment three times on four separate days.
4. Explain why Sean used a column graph rather than another type of graph to present his results.

Evaluate and create

5. Suggest how Sean could improve the reliability and accuracy of his experiment.
6. In your opinion, is Sean's conclusion valid? Give reasons for your answer.

Fully worked solutions and sample responses are available on your digital formats.

1.11 Using secondary sources to draw conclusions

LEARNING INTENTION

At the end of this subtopic you will be able to understand the importance of secondary evidence and use evidence that is valid and provides appropriate evidence to assist in drawing conclusions.

1.11.1 Ensuring validity in secondary sources

Part of science is being able investigate not just primary sources that you obtain in direct observation, but also secondary sources.

It is important that any secondary evidence you use is valid and provides appropriate evidence to assist in drawing conclusions.

Secondary evidence that can assist you should have:
- a basis in facts derived from studies with high validity and minimal bias
- statistical evidence to support conclusions
- a clear distinction between correlation and causation — two variables may often have some correlation (they both increase, for example), but have no causation (one variable does not cause the change in value in the other)
- data from investigations that have a reproducible and reliable method (for example, using a large sample size and various control groups)
- peer-reviewed research formed from scientific ideas.

Using valid secondary evidence allows for the development of evidence-based arguments and for better conclusions to be drawn.

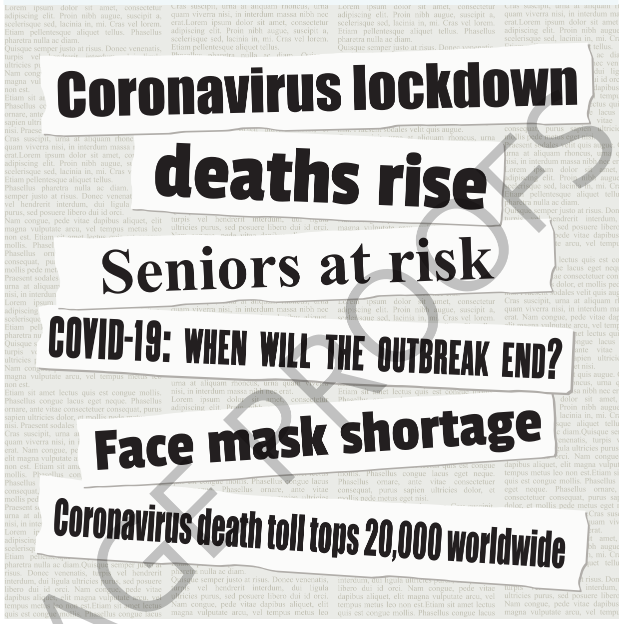
1.11.2 Is the evidence reliable?

When exploring secondary evidence, it is important to ensure that it is reliable.

Much of the information available to the public often lacks reliability and can confuse individuals about the key scientific ideas.

Many argue that we are currently in an age of information overload. We are constantly being bombarded with information from a variety of sources, many of these associated with the media. Some of the information that you are exposed to may not be accurate or the whole story. The information may be **biased** in the selection, emphasis, word choice and context used. It is important that when interpreting information, you are aware of these possible biases. You also need to be aware of your own biases!

FIGURE 1.35 Do you know the full story looking at a headline?



In making sense of this new information, you need to focus on the ways in which you build your knowledge. How you — as a 'learner' at the centre of your learning — use your senses (e.g. sight, hearing, smell, touch and taste) to *perceive* your world, and emotion, reason and language to *interpret* what you sense.

It is important to consider all types of science- related media to help critically analyse the validity of information and to evaluate conclusions.

Where can we get reliable information?

Government websites and those from educational institutions and established organisations are usually reliable. When using other websites, it is a good idea to look for dates and research the authors to see if the information is verifiable and current. You should try to use multiple sites to verify the data, and be cautious of sites that can be altered by the public (such as Wikipedia or social media). Google Scholar can be a good starting point to help find reliable sources of information.

DISCUSSION

Are websites that can be edited by the general public always unreliable? Discuss this and present your ideas to the class.

It can be helpful to look at the domain name of a website (the letters towards the end of the URL). Remember that a website address ending in '.au' means that it is registered in Australia, but some non-governmental Australian websites are registered in the United States and will not include the '.au'.

Peer-reviewed journals in science are also reliable sources of evidence, as the articles have been reviewed for quality of research, experimental reproducibility, accuracy and validity, and adhere to the required standards of a journal, ensuring articles are not biased.

It is also important to ensure that sites or authors of content being researched do not have any conflict of interest. For example, if an article is talking about an incredible new medication and data on this, but the author or organisation are funded by the drug manufacturer, it is an example of a potential conflict of interest.

biased inclined towards a preference or prejudice

peer-reviewed evaluated scientifically, academically, or professionally worked by others working in the same field

TABLE 1.6 Examples of generic top-level domain names

Domain name contains	Source
.gov.au	Australian federal, state, territory and local government entities; cannot be edited by the general public
.gov	United States government entities; cannot be edited by the general public
.edu.au	Limited to Australian educational institutions including schools and universities; cannot be edited by the general public
.edu	Largely limited to American higher educational institutions (universities and colleges; not schools); cannot be edited by the general public
.org	Intended for use by not-for-profit organisations; some web pages can be edited by the public (for example, Wikipedia.org)
.com.au	Intended for commercial use, but now used within Australia across a range of sectors including businesses, not-for-profits, schools, individual people
.com	Intended for commercial use, but now used within the United States across a range of sectors including businesses, not-for-profits, schools, individual people
.net	Intended for networking technology organisations such as internet service providers, but now used across a range of sectors including businesses, not-for-profits, schools, individual people

on Resources

eWorkbooks Evaluating media reports (ewbk-6565)

Summarising secondary sources (ewbk-6567)

1.11 Exercise

learn**on**

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3	Questions 2, 4	Questions 5, 6

Remember and understand

1. Explain the difference between a secondary and a primary source.
2. Outline three factors that are seen in reliable sources of secondary evidence.

Apply and analyse

3. Explain how you may be able to use editable websites such as Wikipedia to find reliable sources of information.
4. Explain why you might also use secondary evidence in a scientific report if you have already gathered primary evidence.
5. Explain the link between bias and conflict of interest.

Evaluate and create

6. A student has used the following sources of information for their secondary evidence to support findings they made in an investigation:
   - three peer-reviewed journals
   - an article by the Department of Health on the Australian government website
   - a Twitter post by a well-known immunologist
   - two articles from the *Herald Sun* site (heraldsun.com.au).

   Evaluate each of the sources of secondary evidence, summarising assumptions that can be made about their reliability and validity.

Fully worked solutions and sample responses are available on your digital formats.

1.12 Using spreadsheets

LEARNING INTENTION

At the end of this subtopic you will be able to use a spreadsheet to record, graph and analyse data.

1.12.1 The advantages of spreadsheets

A spreadsheet is a computer program that can be used to organise data into columns and rows.

Once the data are entered, mathematical calculations, such as adding, multiplying and averaging, can be carried out easily using the spreadsheet functions.

Spreadsheets have many advantages over handwritten or word-processed results. For example, with spreadsheets you can:

- make calculations quickly and accurately
- change data or fix mistakes without redoing the whole spreadsheet
- use the spreadsheet's charting function to present your results in graphic form.

1.12.2 Elements of a spreadsheet

Although there are a number of spreadsheet programs available, they all have the same basic features and layout, as shown in example 1. The data shown are from a student research project about the different factors on the growth of bean plants.

1.12.3 Entering data into cells

You can enter different types of data into a cell:

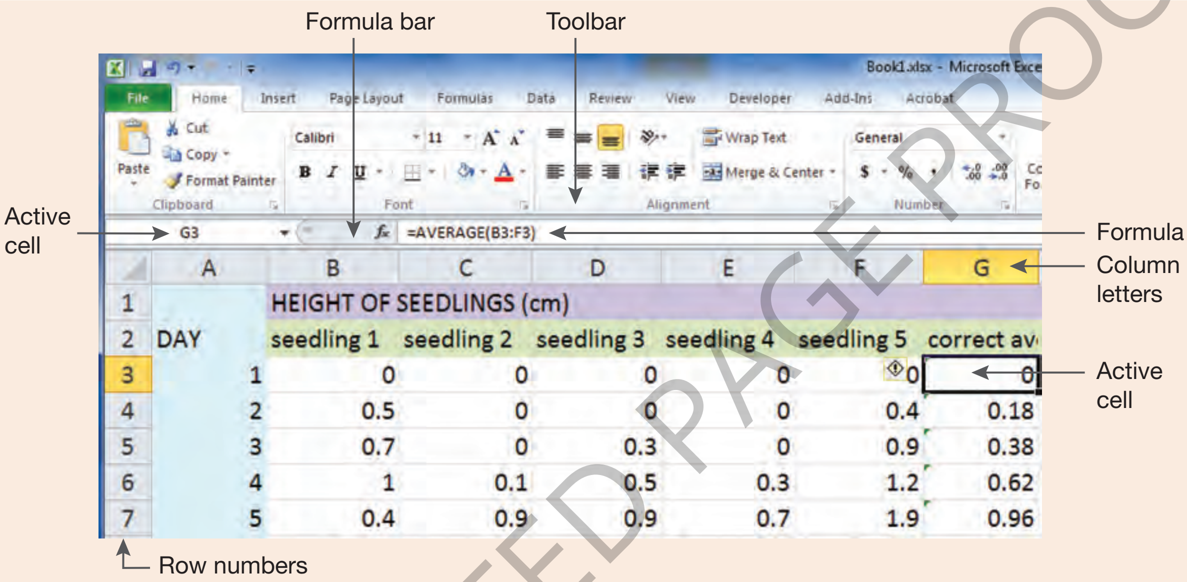
- a number or value
- a label; that is, text (for titles and headings)
- a formula (an instruction to make a calculation).

Decide in which cell you want to insert the data (the active cell). Type the data in the cell and press 'Enter'. To edit or change the data, simply highlight the cell and type in the new data — it will replace the old data when you press 'Enter'. Example 2 shows a spreadsheet in which data have been entered.

CASE STUDY: Example 1

- At the top of the spreadsheet are the toolbar and formula bar.
- A *row* is identified by a number; for example, ‘row 1’ or ‘row 2’.
- A *column* is identified by a letter; for example, ‘column A’ or ‘column B’.
- A *cell* is identified by its column and row address. For example, ‘cell G3’ refers to the cell formed by the intersection of column G with row 3. In this example, cell G3 is the active cell (shown by its heavy border). The active cell address and its contents (once data are entered) are shown to the left of the formula bar.
- A *range* is a block of cells. For example, ‘range C3:F4’ includes all the cells in columns C through to F and rows 3 through to 4.

FIGURE 1.36 Key components in an excel spreadsheet



1.12.4 Creating formulae

To create a formula, you need to start with a special character or symbol to indicate that you are keying in a formula rather than a label or value. This is usually one of the symbols =, @ or +, depending on the spreadsheet program. For example, a formula to add the contents of cell B1 to cell C1 would take one of the following forms: =B1+C1 or @B1+C1 or +B1+C1.

Once you have entered the formula in a cell, the result of the calculation, rather than the formula, will be shown. The formula can be seen in the status bar when the cell is active (see example 2.). If you subsequently needed to change the values in B1 or C1, the spreadsheet will automatically use the formula to recalculate and show the new result.

The symbols used for mathematical operations in spreadsheets are:

+ for addition

– for subtraction

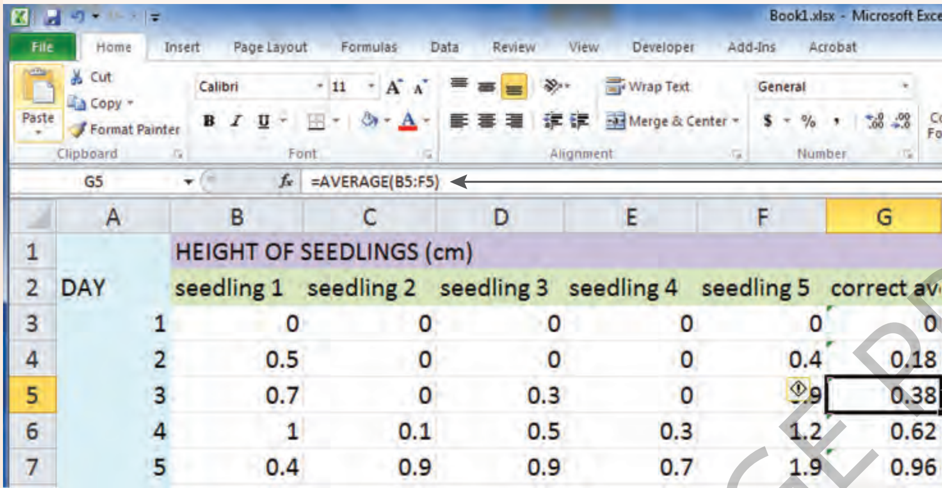
* for multiplication

/ for division.

CASE STUDY: Example 2

The spreadsheet in example 1 has been further developed. Formulae have now been entered to average the heights of the seedlings.

FIGURE 1.37 Using an Excel sheet to calculate averages



Archive cell contents

This is the active cell. The formula in the bar above is the formula for this cell.

1.12.5 Using functions

Some common types of calculations are built into the spreadsheet, so that you don't always need to type out the full formulae. These are called **functions**. All functions have two parts: the name and a value (called the **argument**) that the function will operate on. The value is normally placed in parentheses, (), and can be written as a set of numbers or as a range (a block of cells). For example, a function to calculate the average of the amounts entered in cells B1, B2, B3 and B4 would be written: =AVERAGE(B1:B4).

TABLE 1.7 Common spreadsheet functions

Name	Application	Example	Result
AVERAGE	calculates the average of the argument values	=AVERAGE(1,2,3,4)	2.5
COUNT	counts the number of values in the argument	=COUNT(A3:A6)	4
MAX	returns the largest value in the argument	=MAX(1,9,5)	9
MIN	returns the smallest value in the argument	=MIN(1,9,5)	1
MODE	returns the most common value in the argument	=MODE(1,1,5,5,1)	1
MEDIAN	returns the median value of the argument values	=MEDIAN(1, 2, 3, 5, 6)	3
ROUND	rounds the argument to the number of decimal places specified	=ROUND(12.25,1)	12.3
SUM	calculates the sum of the values in the argument	=SUM(1,9,5)	15
MEDIAN	returns the median (middle) value of the argument values	=MEDIAN(1,2,3,4,5)	3

1.12.6 Copying cells

Spreadsheets have a command that allows you to copy a formula or value from one cell to another cell (or into a range of cells). This is usually found in the *Edit* menu (*Fill Down* or *Fill Right*). The way a formula is copied depends on whether the cell references use:

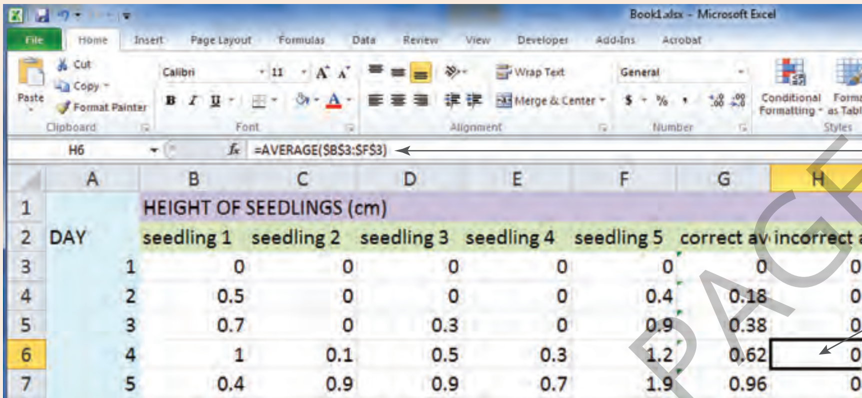
functions common type of calculation built into spreadsheets

argument value that a function in a spreadsheet will operate on

- **relative referencing**, which you use when you want the cell address in the formula to change according to the relative location of the cell that you have copied it to. Example 2 in section 1.7.4 uses relative referencing. The formula AVERAGE(B5:F5) in the active cell G5 was copied downwards, so that there was no need to type the formulae in the rest of the column. The formula in the next cell (G6) is therefore AVERAGE(B6:F6) and so on.
- **absolute referencing**, which you use when you want a cell address in the formula to be constant, no matter where it is copied to. Absolute referencing is denoted by the symbol $ placed in the cell address. For example, B3 (see example 3).

CASE STUDY: Example 3

FIGURE 1.38 Using absolute referencing in a spreadsheet



The formula has a $ sign in front of the cell coordinates, so that the coordinates do not adjust automatically as the row number changes.

The formula above is the formula for this cell in row 5.

1.12.7 Formatting cells

Investigate your spreadsheet program (most come with a tutorial) to learn how to use other useful features such as:

- adding and deleting rows or columns (useful if you have forgotten to include some calculations in your planning or decide you don't need some items)
- changing column widths (to show the full cell contents when the data are longer than the default column width) and changing row heights so that you can use larger font sizes for titles and headings
- inserting horizontal or vertical lines to improve the presentation of your spreadsheet
- changing cell formats to control how the data are to be displayed, such as using different fonts and character styles (underlining, bold, italic).

You can also format numeric values in a variety of ways. For example, the *Fixed* or *Number* format will display values to the number of specified decimal places. The *Percent* format will display values as a percentage, to the number of specified decimal places.

Once you have keyed in your data and included any necessary calculations, print out your spreadsheet and save it to a disk so that you can store the document and use it later.

1.12.8 Spreadsheet graphics

The three main types of graphs — pie, bar and line graphs — can usually be produced by a spreadsheet. It means that you can easily display your results graphically, but you still need to decide which is the most appropriate type of graph for your data.

relative referencing used in a spreadsheet when the cell address in the formula is changed

absolute referencing used in a spreadsheet when a cell address in the formula remains constant, no matter where it is copied to

The first step in producing a spreadsheet graph is to select the block of the cells that contains the data to be graphed. Use the spreadsheet's charting function, which usually brings up a window where you can indicate the type of graph, and add title and label details. When you are satisfied with the result, you can display and print out your graph.

on Resources

eWorkbooks Spreadsheeting and graphing (ewbk-6569)
Calculating using a spreadsheet (ewbk-6571)

1.12 Exercise

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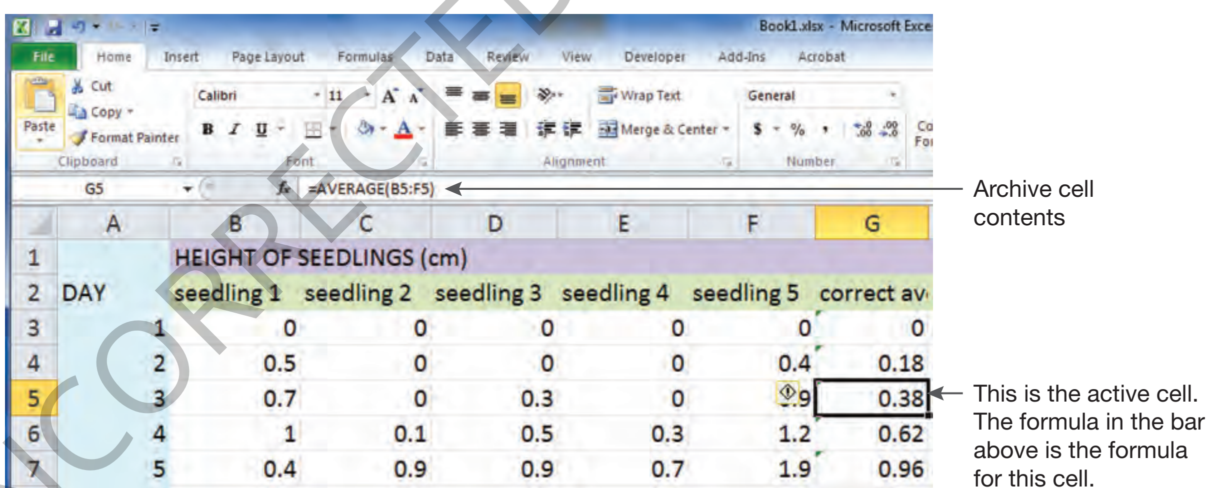
Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1	Questions 2, 3	Questions 4

Remember and understand

1. Look at the section of a spreadsheet provided and answer the following questions.



   a. What does cell G3 contain?
   b. Does cell E2 contain a value or a label?
   c. If the formula in cell G4 is AVERAGE(B4:F4), what would the formula be in cells G5 and G6?
2. The following table shows the results of an experiment that tested the amount of time taken for eucalyptus oils and other substances (0.1 mL of each) to evaporate at a constant temperature. The experiment was performed twice.
   a. Enter the data into a spreadsheet.
   b. Use the spreadsheet function to calculate the average time that each substance took to evaporate.

TABLE Time taken to evaporate different substances

Substance	Time (s)	
	Trial 1	Trial 2
Methylated spirits	4.17	1.85
Turpentine	63.48	43.02
Water	54.42	57.05
Oil from *E. rossi*	195.92	191.23
Oil from *E. nortonii*	103.99	105.39

Apply and analyse

3. The following table shows the distance travelled by Jesse at 3-second intervals during a 100-metre sprint. The data were recorded during the sprint by attaching a paper tape to Jesse's waist. As he ran, the tape was pulled through a timer that printed a dot every 3 seconds.

TABLE Distance and speed traveled in 3-second intervals

Time (s)	Distance travelled in time interval (m)	Average speed for time interval (m/s)
0	0	
3	35	
6	25	
9	15	
12	15	
15	10	

a. Enter the data into a spreadsheet. Calculate the average speed travelled in each 3-second interval by applying a formula to the first cell in the column, and then copying it down. Remember that average speed can be calculated by dividing the distance travelled by the time taken:

$$\text{Speed} = \frac{\text{distance}}{\text{time}}$$

b. Calculate Jesse's average speed over the total time.

Evaluate and create

4. The following data were collected by two car servicing centres in Canberra in 1998, at the request of a student. The table shows the level of carbon monoxide and carbon dioxide emissions (as a percentage of total emissions) from cars of various ages.

TABLE Carbon monoxide and carbon dioxide emissions of cars by year of manufacture

Year car manufactured	Carbon monoxide (%)	Carbon dioxide (%)
1977	3.17	11.8
1983	2.48	13.6
1985	3.7	11.4
1987	1.6	13.1
1989	1.08	10.2
1996	0.19	15.2

a. Enter the data into a spreadsheet and create a graph to display these results.
b. Create formulae to work out the average carbon monoxide and carbon dioxide emissions for:
  i. cars manufactured up to 1985
  ii. cars manufactured from 1987 onwards.
c. Car manufacturers were required to install catalytic converters in cars made after 1986. Catalytic converters cut down carbon monoxide emissions by converting some of the carbon monoxide to carbon dioxide. What can you conclude from these data about the success of catalytic converters?

Fully worked solutions and sample responses are available in your digital formats.

1.13 SkillBuilder — Using a spreadsheet

1.13.1 How do you use a spreadsheet to record, analyse and graph your results?

Spreadsheets, through programs such as Excel, provide very powerful ways to identify trends and patterns in your data. They allow for data to be recorded in cells to format tables, and allow for the quick analysis of data and creation of different types of graphs.

Select your learnON format to access:

- an overview of the skill and its application in science (Tell me)
- a video and a step-by-step process to explain the skill (Show me)
- an activity and interactivity for you to practise the skill (Let me do it)
- questions to consolidate your understanding of the skill.

on Resources

eWorkbook	SkillBuilder: Using a spreadsheet (ewbk-6573)
Video eLesson	Using a spreadsheet (eles-4230)
Interactivity	Using a spreadsheet (int-8160)

1.14 Using data loggers and databases

LEARNING INTENTION

At the end of this subtopic you will be able to use a data logger and create a simple database.

1.14.1 The data logger

A data logger is a device that stores a large number of pieces of information (data) sent to it by sensors attached to it.

The data logger can transfer this data to another device, such as a graphing calculator or, more commonly, a computer, which can use data logger software or a spreadsheet program to manipulate the data (see section 1.7.1). Usually the computer or calculator graphs the collected data, and we can use these graphs to see patterns and trends easily.

When can a data logger be used?

Data loggers are particularly useful whenever an experiment requires several successive measurements. Sometimes, these measurements will take place over several hours or days — such as when measuring the way air pressure varies with the weather. Sometimes, many measurements must be taken over a short time interval — such as when measuring changes in air pressure as sound waves pass by. Data loggers are very flexible and can help scientists gather and analyse data for these types of experiments, as well as many others.

CASE STUDY: Using data loggers in endothermic and exothermic reactions

In an experiment, we investigate temperature changes in chemical processes. In addition to the laboratory equipment required for this experiment, including safety glasses, we will need a data logger with a temperature sensor attached to it. The data logger will need to be attached to a computer on which the data logger software has been installed.

Citric acid and baking soda

For this part of the experiment, we will need baking soda, citric acid, a beaker, a foam cup, other necessary laboratory equipment such as safety glasses, as well as a data logger and temperature sensor. We will use 30 mL of citric acid and 10 g of baking soda. These items are shown in figure 1.39. We set the run time to 200 seconds and the data collection rate to once per second. We insert the temperature sensor into the acid, press a button on the data logger to start data collection and then add the baking soda to the acid. The data logger collects the data, which the computer software automatically graphs after completion, as shown in figure 1.40.

FIGURE 1.39 The equipment required for citric acid and baking soda

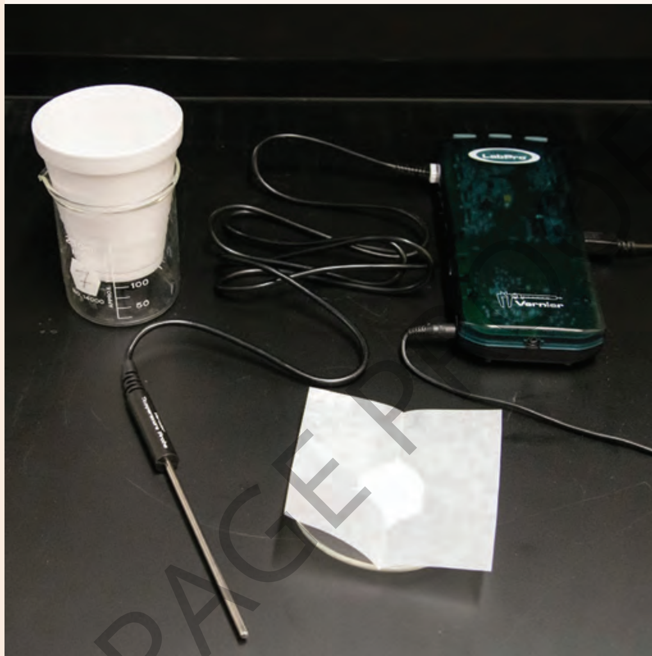
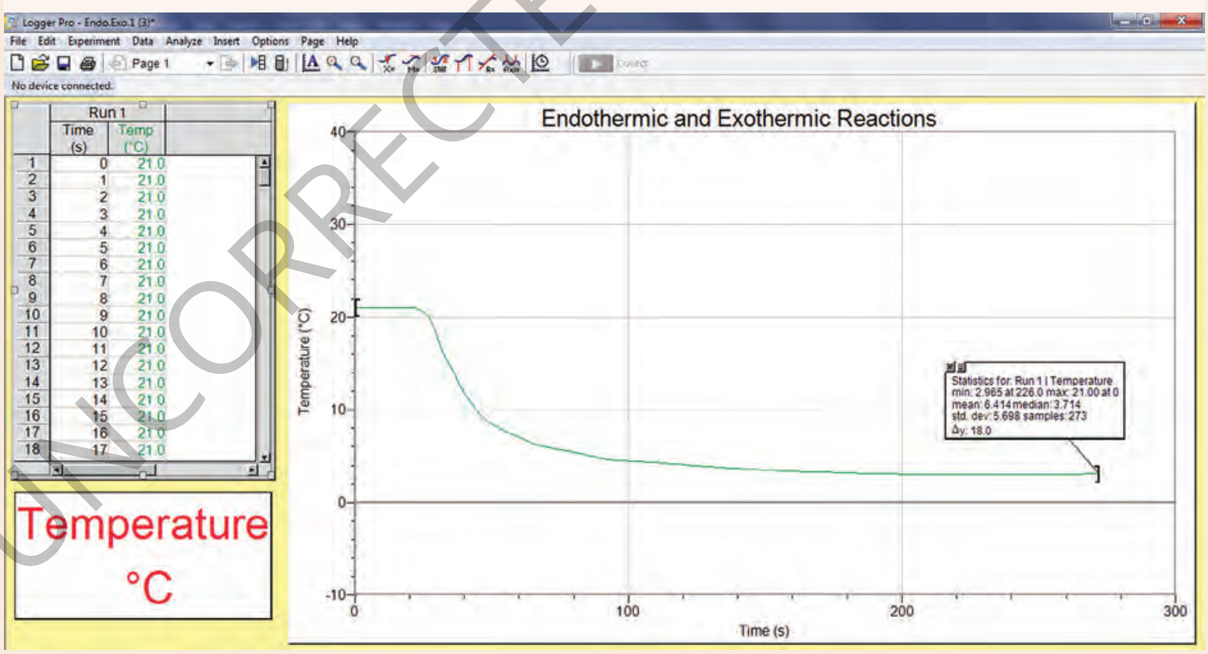


FIGURE 1.40 Graphed data from a data logger in the investigation



elog-0743

INVESTIGATION 1.3

Exothermic and endothermic processes

Aim

To use a data logger to measure change in temperature and compare this to using a thermometer

Materials

- safety glasses
- 20 g baking soda (dissolved in 100 mL water)
- 60 mL citric acid
- thermometer
- 1 test tube
- test- tube rack
- balance
- stirring rod
- temperature probe
- data logger
- laptop

Method

1. Pour 10 mL of citric acid solution into a test tube in a test-tube rack.
2. Place a thermometer in the water in the test tube and allow it to come to a constant temperature.
3. Record the temperature of the water.
4. Use a balance to weigh 3 g of baking soda; add it to the water in the test tube and stir gently.
5. Observe the temperature of the solution as the baking soda dissolves in the water. Record the final temperature of this solution.
6. Repeat the above process using a data logger and temperature probe instead of the thermometer.

Results

Record your results for both your investigation with the thermometer and with the data logger.

Discussion

1. How did the results from the thermometer and results for the data logger compare?
2. What variables did you need to keep constant?
3. Outline any errors that may have occurred in your investigation.
4. Describe three suggestions for improvement.
5. Which method was more accurate? How do you know?

Conclusion

Summarise your findings about using a data logger to measure change in temperature and compare this with a thermometer.

1.14.2 Using databases

Databases are simply information or data arranged in one or more tables. We use databases every day; for example, when we look up information in the index of a book.

An electronic database is a powerful computer application and is an important tool for a business, an organisation or a scientist. A database's design is crucial to its usefulness, so a database must be designed with ease of searching uppermost in mind. Many programs can be used to create electronic databases, including Microsoft Access.

on Resources

Weblink How to use Microsoft Access

1.14 Exercise

To answer questions online and to receive **immediate feedback** and **sample responses** for every question, go to your learnON title at www.jacplus.com.au.

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 3	Questions 2, 5	Questions 4, 6

Remember and understand

1. Describe the purpose of a data logger.
2. List three examples where you could use a database in everyday life.
3. Outline two disadvantages of using a data logger.

Apply and analyse

4. Look at the graph shown in the figure 1.40 of the collected data produced by the computer for *citric acid and baking soda*.
   a. What was the temperature of the acid at the start of the experiment?
   b. What was the lowest temperature that the solution of acetic acid and baking soda reached? How long after first adding the baking soda did this occur?
   c. Is dissolving baking soda in citric acid an exothermic or endothermic process? How do you know?
5. Sensors are the devices that take the measurements that the data logger collects. Think of scientific investigations that could use data collected by sensors that measure:
   a. electric current
   b. acidity of solutions
   c. concentration of carbon dioxide in the air
   d. total dissolved solids (salt content)
   e. light intensity.

Evaluate and create

6. List the advantages of using a data logger over taking the measurements manually. Describe an experiment in which using a data logger provides an advantage over manual data collection.

Fully worked solutions and sample responses are available in your digital formats.

1.15 Review

Access your topic review eWorkbooks

Select your pathway

TOPIC REVIEW LEVEL 1	TOPIC REVIEW LEVEL 2	TOPIC REVIEW LEVEL 3
ewbk-6575	ewbk-6577	ewbk-6579

on Resources

1.15.1 Summary

Thinking flexibly

- It is important to think both critically (use information to guide decision-making) and flexibly (consider different viewpoints) in science.
- Some ways to analyse science include: inductionism (proven knowledge through first-hand data), falsification (theories are educated guesses that cannot be proven beyond reasonable doubt) and through paradigms (ways of thinking).
- Paralanguage is communicating a specific meaning.
- Parts of communication include the ability to apply, explain and interpret, and show empathy, self-knowledge and perspective.
- A theory is a well-supported explanation of a phenomena, based on investigations, research and observations. In science, theories are often tested using the scientific method.

Science and ethics

- In science, ethical considerations need to be balanced with goals, rights, needs and duties.
- Ethics involve your moral values and interact with science in a variety of ways.
- There are five main principles of ethics: integrity, justice, beneficence, non-maleficence and respect/autonomy.

Designing and conducting your own investigation

- You should follow the scientific method when conducting an investigation.
- After you select a topic, you should ensure that you turn this into a research question, which is specific and able to be investigated.
- Variables are factors that an investigator can control, change or measure.
- An independent variable is manipulated by the investigator (e.g. the type of metal examined).
- A dependent variable is measured by the investigator and is influenced by the independent variable (e.g. the melting temperature of a metal).
- A controlled variable is one that is kept the same in an investigation — there are usually numerous controlled variables in an experiment.
- An aim is a one- to two-sentence outline of the purpose of the investigation, linking the dependent and independent variables.
- A hypothesis is a tentative, testable and falsifiable statement for an observed phenomenon and acts as a prediction for the investigation.
- Part of scientific method or process is designing an experiment, conducting the experiment and analysing the results.
- You should ensure that the data you collect is precise and accurate.
- Graphs and tables are very important and display your results to see trends and patterns.

Using secondary sources to draw conclusions

- It is vital to ensure that secondary data used is both reliable and valid.
- Secondary data can help support the findings made in investigations and the primary data obtained.
- Secondary data used should not be biased and should have no conflict of interest.

Using spreadsheets, data loggers and databases

- Spreadsheets and databases can help organise your information.
- Spreadsheets contain many functions that can be used to extract information from data or perform calculations automatically.
- Data loggers allow you to get more accurate information over time.
- Some data loggers are also able to plot the data they record to provide accurate graphs automatically.
- Databases are information or data arranged in one or more tables. Spreadsheets can be used to draw conclusions about the data in a database.

1.15.2 Key terms

absolute referencing used in a spreadsheet when a cell address in the formula remains constant, no matter where it is copied to
accurate an experimental measurement that is close to a known value
analyse examine methodically and in detail to answer a question or solve a problem
argument value that a function in a spreadsheet will operate on
beliefs feelings or mental acceptance that things are true or real
biased inclined towards a preference or prejudice
blog a personal website or web page where an individual can upload documents, diagrams, photos and short videos
calibration the process whereby a measuring instrument is restored to accuracy
control an experimental set-up in which the independent variable is not applied
controlled variable the conditions that must be kept the same throughout an experiment
dependent variable a variable that you measure that is influenced by changes to the independent variable
duty moral obligation or responsibility
ethics the system of moral principles on the basis of which people, communities and nations make decisions about what is right or wrong
fair testing a method for determining an answer to a problem without favouring any particular outcome
falsification a theory stating that no theory is ever proven beyond all doubt
functions common type of calculation built into spreadsheets
genetic modification the technique of modifying the genetic structure of plants, making it possible to design plants that have certain characteristics
goal something that you want to achieve
human error individual mistakes made in investigations
independent variable a variable that is deliberately changed during an experiment
inductionism a theory stating that with enough evidence, scientific theories can become universal laws
judgements opinions formed after considering available information
logbook a complete record of an investigation from the time a search for a topic is started
meniscus the curve seen at the top of a liquid in response to its container
need something that you require
opinions making judgements about the desirability of something
paradigms generally accepted perspectives, ideas or theories at a particular time
paralanguage parts of communication used to modify meaning and show attitudes
parallax error the effect where the position or direction of an object appears to differ when viewed from a different position
peer-reviewed evaluated scientifically, academically, or professionally worked by others working in the same field
placebo a medicine or procedure that has no therapeutic effect, used as a control in testing new drugs
precise multiple measurements of the same investigation being close to each other
proximate rules govern the physical distance that is comfortable between people
random error an error that affects the precision of results
reflectiveness being self-aware, open-minded and sometimes standing back and looking at the big picture
relative referencing used in a spreadsheet when the cell address in the formula is changed
reliable data data that can be replicated in different circumstances but same conditions
replication repeating of an experiment to make sure you have collected reliable data
resilience the ability to tolerate feeling a little uncomfortable sometimes
resourcefulness taking responsible risks and using a range of appropriate learning tools and strategies
responsibility being able to manage yourself and your learning

right something you feel that you are entitled to

risk assessment a procedure that identifies the potential hazards of an experiment and gives protective measures to minimise the risk

scientific method a systematic approach to planning, undertaking and analysing research

systematic error an error (often due to equipment) that affects the accuracy of results

theory a well-supported explanation of a phenomenon based on facts that have been obtained through investigations, research and observations

valid sound or true. A valid conclusion can be supported by other scientific investigations

values represent a deep commitment to a particular issue and serve as standards for decision making

on Resources

Digital document	Key terms glossary (doc-35060)
eWorkbooks	Study checklist (ewbk-6581) Literacy builder (ewbk-6582) Crossword (ewbk-6584) Word search (ewbk-6586)
Practical investigation eLogbook	Topic 2 Practical investigation eLogbook (elog-0737)

1.15 Exercise

learnon

Select your pathway

LEVEL 1	LEVEL 2	LEVEL 3
Questions 1, 4, 7, 10, 12	Questions 2, 5, 8, 11, 13	Questions 3, 6, 9, 14

Remember and understand

1. Match the words in the following list with their meanings.

Words	Meanings
a. Conclusion	A. Concerns that deal with what is morally right or wrong
b. Abstract	B. The variable that is deliberately changed in an experiment
c. Discussion	C. The part of a journal article where a brief overview of the article is given
d. Results	D. A list of steps to follow in an experiment
e. Hypothesis	E. The answer to the aim or the problem
f. Ethical considerations	F. A list of equipment needed for the experiment
g. Independent variable	G. The variable that is measured in an experiment
h. Dependent variable	H. States what was seen or measured during an experiment. May be presented in the form of a table or graph.
i. Method	I. A sensible guess to answer a problem
j. Apparatus	J. The part of a report where problems with the experiment and suggestions for improvements are discussed

2. Miranda wants to test the following hypothesis: Hot soapy water washes out tomato sauce stains better than cold soapy water.

TABLE The effect of water temperature on stains during washing

Water temperature (°C)	Observations
20	Dark stain left after washing
40	Faint stain left after washing
60	No stain left after washing
80	No stain left after washing

a. List the equipment she will need.
b. Identify the independent and dependent variables in this investigation.
c. List five variables that will need to be controlled.
d. Outline a method that could be used to test the hypothesis.
e. Miranda's results are shown in the table.
f. Write a conclusion based on Miranda's results.

3. Gemina and Habib want to investigate whether the type of surface affects how high a ball bounces. Habib thought the ball would probably bounce the highest off a concrete floor. They dropped tennis balls from different heights onto a concrete floor, a wooden floor and carpet. Their results are shown in the following table.

TABLE The average height of a ball bouncing on different surfaces at different distances

Distance ball dropped (cm)	Average height of bounce (cm)		
	Concrete	Wood	Carpet
25	22	14	8
50	46	34	18
75	70	50	26
100	94	66	34
125	X	85	Z
150	128	94	48
175	129	Y	50
200	130	100	51

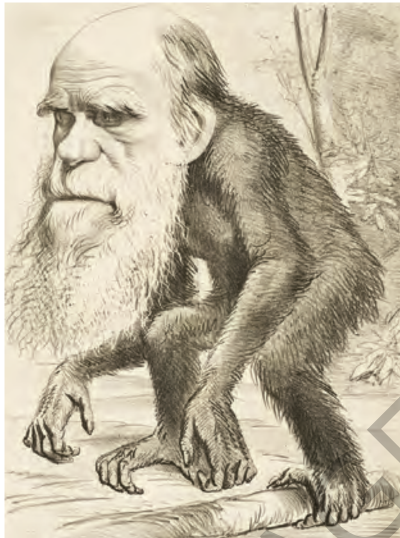
a. Write a hypothesis for this experiment.
b. Construct a line graph of Gemina and Habib's results.
c. Use your graph to estimate the values X, Y and Z.
d. Identify two variables that had to be kept constant in this experiment.
e. Identify two trends in the results.
f. Do the results support the hypothesis you wrote?
g. Predict how high the tennis ball would bounce off each floor if it was dropped from a height of 225 cm.

4. List some of the factors affecting the decision about whether money is spent on finding a cure for a particular disease.

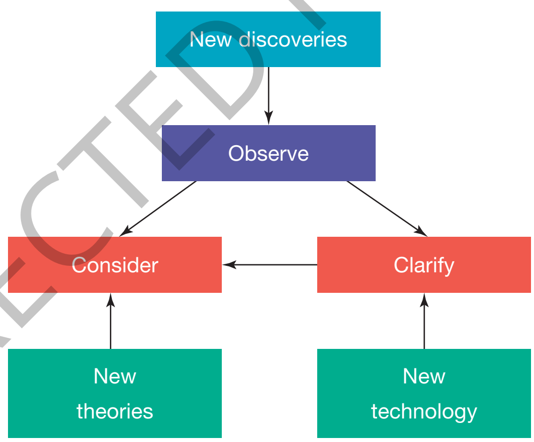
Apply and analyse

5. Should farmers be allowed to plant the type of crop they believe produces the best yield, irrespective of whether others object to the manner in which the crop was bred? Justify your response.
6. Charles Darwin's theory of evolution (see topic 3) sat unpublished for over ten years before it was published as *On the Origin of Species*.
   a. Research and outline why it took him such a long time to make his ideas public.
   b. Many caricatures of Charles Darwin have appeared over the years. Suggest what the creator of the cartoon is suggesting. Do you consider this accurate in terms of Darwin's theory? Explain your answer.
   c. Outline the key ways in which the theory of evolution differed from the accepted theological view of the time.
   d. Identify the other scientist who is responsible for proposing the theory of evolution. Suggest why he is not as well known as Charles Darwin.

e. Identify at least five other people involved in the development and acceptance of the theory of evolution and state their key contribution.
f. If a scientist were to propose a new theory about creation that significantly differed from the currently accepted view, suggest how this might be received by the scientific community and the general public.
g. Suggest a possible alternative to the theory of evolution. Provide reasons to support your theory.



7. Carefully observe the flowchart figure.



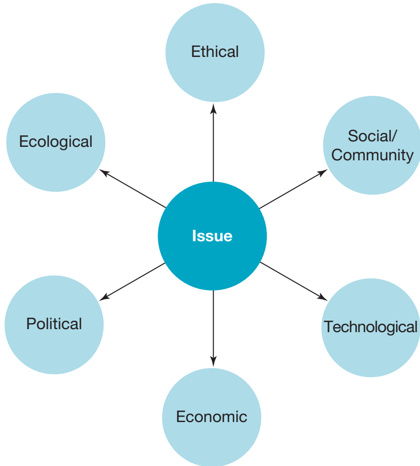
a. Do you think that this figure effectively summarises how we mix new information to rethink ideas and improve our scientific knowledge?
b. Can you think of an example of how our scientific knowledge has developed in a way similar to that suggested by the model?
c. Suggest how the model could be improved.

8. Research examples of drugs or tests that are known to encourage people to tell the truth.
a. Find out how they work.
b. Do you believe that you have the right not to be forced to tell the truth? Explain why.
c. Do you think that lie detector tests and truth serums or treatments should be used to force people to tell the truth or test whether they are telling the truth? Justify your response.

Evaluate and create

9. Use the issues mind map to help you identify various perspectives on one of the following issues.
- Watering of gardens should be illegal.

- Cars should be driven only when there are at least four occupants.
- Scientists should be allowed to research whatever they want.
- If a vaccine for the dangerous variant of H5N1 is synthesised, it should be given only to children under 10 years of age.



10. Scientific ideas and theories can change over time. Does this mean that those previously accepted were totally wrong? Discuss and explain your response.
11. Suggest consequences that our increased knowledge of the structure and function of DNA has for both individuals and the society in which we live.
12. Should the labelling of genetically modified foods be compulsory? Justify your response.
13. Carefully read through each of the following statements. For each statement, decide whether you agree or disagree and then justify your response.
    - Scientific discoveries and understanding often rely on developments in technology and technological advances.
    - Financial backing from governments or commercial organisations determines the types of scientific research and development that are carried out.
    - Scientific understanding, models and theories are changed over time through a process of review by the scientific community.
    - The focus of scientific research can be influenced by the current values and needs of society.
    - Advances in science and technologies can have a significant effect on people's lives.
    - Scientific knowledge should be used to evaluate whether you should accept claims, explanations or predictions.
14. Computer animations have greatly increased our knowledge and improved our understanding of how our world operates. Research and communicate other examples of how information technology has been used to enhance our scientific knowledge and understanding.

Fully worked solutions and sample responses are available in your digital formats.

on Resources

eWorkbook Reflection (ewbk-3038)

teachon

Test maker
Create customised assessments from our extensive range of questions, including teacher quarantined questions.
Access the assignments section in learnON to begin creating and assigning assessments to students.

RESOURCE SUMMARY

on Resources

Below is a full list of rich resources available online for this this topic. These resources are designed to bring ideas to life, to promote deep and lasting learning and to support the different learning needs of each individual.

1.1 Overview

eWorkbooks
- Topic 1 eWorkbook (ewbk-6530)
- Student learning matrix (ewbk-6534)
- Starter activity (ewbk-6532)

Video eLesson
- Meet Professor Veena Sahajwalla (eles-1071)

Practical investigation eLogbook
- Topic 2 Practical investigation eLogbook (elog-0737)
- Student learning matrix (ewbk-6534)
- Starter activity (ewbk-6532)

1.2 Thinking flexibly

eWorkbook
- Summary of different thinking tools (ewbk-6537)

Video eLessons
- Dark matter labs (eles-2688)
- Theoretical physicists of the twentieth century (eles-2687)
- Australia's top scientists (eles-1079)
- Hesperides science (eles-1078)

1.3 Heliobacter pylori bacteria (eles-2691)

eWorkbooks
- Science and ethics (ewbk-6539)
- Difficult decisions (ewbk-6541)

Video eLesson
- Heliobacter pylori bacteria (eles-2691)

1.4 Designing and conducting your own investigation

eWorkbooks
- Setting up a logbook (ewbk-6543)
- Variables and controls (ewbk-6545)
- Organising and evaluating results (ewbk-6547)
- Components of a practical report (ewbk-6549)

Video eLesson
- Is this a good experiment? (eles-2630)

Interactivity
- Sector graphs or pie graphs (int-4061)

1.5 SkillBuilder — Controlled, dependent and independent variables

eWorkbook
- SkillBuilder — Controlled, dependent and independent variables (ewbk-6551)

Video eLesson
- Controlled, dependent and independent variables (eles-4225)

Interactivity
- Controlled, dependent and independent variables (int-8154)

1.6 SkillBuilder — Writing an aim and forming a hypothesis

eWorkbook
- SkillBuilder — Writing an aim and forming a hypothesis (ewbk-6553)

Video eLesson
- Writing an aim and forming a hypothesis (eles-4226)

Interactivity
- Writing an aim and forming a hypothesis (int-8155)

1.7 SkillBuilder — Measuring and reading scales (including parallax error)

eWorkbook
- SkillBuilder — Measuring and reading scales (ewbk-6555)

Video eLesson
- Measuring and reading scales (eles-4227)

Interactivity
- Measuring and reading scales (int-8156)

1.8 SkillBuilder — Creating a simple column or bar graph

eWorkbook
- SkillBuilder — Creating a simple column or bar graph (ewbk-6557)

Video eLesson
- Creating a simple column or bar graph (eles-4228)

Interactivities
- Creating a simple column or bar graph 1 (int-4058)
- Creating a simple column or bar graph 2 (int-4059)

1.9 SkillBuilder — Drawing a line graph

eWorkbook
- SkillBuilder — Drawing a line graph (ewbk-6559)

Video eLesson
- Drawing a line graph (eles-1635)

Interactivity
- Drawing a line graph (int-3131)

1.10 Sample scientific investigation

eWorkbooks

- Scientific investigation examples (ewbk-6561)
- Drawing conclusions (ewbk-6563)

1.11 Using secondary sources to draw conclusions

eWorkbooks

- Evaluating media reports (ewbk-6565)
- Summarising secondary sources (ewbk-6567)

1.12 Using spreadsheets

eWorkbooks

- Spreadsheeting and graphing (ewbk-6569)
- Calculating using a spreadsheet (ewbk-6571)

1.13 SkillBuilder — Using a spreadsheet

eWorkbook

- SkillBuilder: Using a spreadsheet (ewbk-6573)

Video eLesson

- Using a spreadsheet (eles-4230)

Interactivity

- Using a spreadsheet (int-8160)

1.14 Using data loggers and databases

Weblinks

- How to use Microsoft Access

1.15 Review

Digital documents

- Key terms glossary (doc-35060)
- Reflection (ewbk-3038)

eWorkbook

- Reflection (ewbk-3038)

Video eLessons

- Study checklist (ewbk-6581)
- Literacy builder (ewbk-6582)
- Crossword (ewbk-6584)
- Word search (ewbk-6586)

Practical investigation eLogbook

- Topic 2 Practical investigation eLogbook (elog-0737)

To access these online resources, log on to **www.jacplus.com.au**.