NSW GOVERNMENT | Education & Training

MyScience Professional learning

Contents

Knowing and Thinking Level 1

What the experts say

Rick Connor in the 'Science and Technology Literature Review' produced for the Board of Studies, NSW raised many relevant issues.

> *"The primary school years are crucial in developing pupils' longer term interest in science. It is crucial, therefore, for primary teachers to not only set in place the knowledge foundations for continued studies in science, but also to engender in students a passion for science and an understanding of its significance in modern society. Good science pedagogy depends on a knowledge of and proficiency in specific teaching strategies for science. It relies on teachers who are broadly and deeply knowledgeable and sufficiently confident in their knowledge to be able to change and innovate."*

— Rick Connor

Doing science investigations based on a theme related to science is an ideal way of combining knowledge, thinking and doing components of science and provides good science pedagogy. It engages and motivates students and leads to deep understanding.

How can I teach the scientific concepts that underpin the investigation?

Background knowledge about the science phenomenon being investigated is important for the development of worthwhile questions for investigation. It is important not to spend too long doing background research so that insufficient time is left for the planning and conducting of a *MyScience* investigation. Scientific knowledge is constantly growing and changing so the processes of investigation are more important than the presentation of 'facts'.

Watch as students describe the difficulties experienced while doing background research.

When you have taught about topics such as 'life cycles' or 'living and non-living', you would have established student prior knowledge, addressed misconceptions and progressed student understanding to a deeper level. While the content of curricula and syllabuses may change in the finer details, understanding of the basic concepts that underpin students' scientific investigations generally does not radically change. What you have done successfully in the past will still inform your current practice.

MyScience investigations occur within the context of a theme. The theme is expanded into topics. The relationship between topics within the theme can be easily demonstrated through a mind map that is jointly constructed by the teacher and class. This helps students understand how the scientific theme relates to the outside world. By the end of this learning pathway, you should be able to generate a mind map with your class for the theme that is the basis for their scientific investigation.

Watch an Assistant Principal explain how she chose a theme, Mythbusters.

What are the key science concepts for the year of schooling that I teach?

You need to spend time reviewing your current mandatory documents to identify the concepts you will be teaching in association with the students conducting scientific investigations.

The draft Australian Curriculum: Science outlines the following unifying ideas for 5-8 year olds:

- exploration
- observation
- order
- change
- questioning and speculation.

The curriculum focus is 'awareness of self and local world'.

The unifying ideas for 8-12 year olds build on the earlier ones and also include:

- patterns
- systems
- relationships
- evidence and explanation.

The curriculum focus is 'recognising questions that can be investigated scientifically and investigating them'.

The draft Australian Curriculum: Science encompasses the three interrelated areas of Science Inquiry Skills (incorporating skills and understanding of science as a way of knowing and doing), Science as a Human Endeavour (incorporating knowledge and understanding of the personal, social, environmental, cultural and historical significance and relevance of science), and Science Understanding (incorporating knowledge and understanding of the biological, physical, earth and space science). (Science Rationale)

How can I teach students to think scientifically?

You need to be able to support students to solve problems and think logically and critically about issues related to conducting an actual scientific investigation. This may involve the use of metalanguage and processes of making generalisations, identifying cause and effect relationships, making logical predictions, clarifying assumptions and making inferences and deductions. The need to think scientifically and apply scientific knowledge can occur throughout a scientific investigation.

One typical area where you have probably engaged in teaching students about causes and effects are the topics about natural disasters; floods, fires, earthquakes, tsunamis and volcanic eruptions. Recall the strategies you successfully used. Maybe you used flowcharts or the POE strategy — Predict-Observe-Explain. (Alternate link to Predict-Observe-Explain teaching strategy).

What are the key science inquiry skills for the year of schooling that I teach?

The draft Australian Curriculum: Science identifies the following areas of scientific inquiry skills for 8-12 year olds:

- identifying questions and predictions
- deciding investigation methods, including planning fair tests
- using equipment, observing, and measuring
- analysing results and developing explanations
- communicating ideas and understandings
- reflecting on investigation processes.

If you would like to read more deeply about the scientific method there is a link to teachersparadise.com about the Scientific Method.

Another useful web site for background reading is at the University of Tasmania on working scientifically.

In *MyScience* the emphasis is on students conducting a scientific investigation that is a fair test. There are five other types of investigations that students may undertake in the context of Science and Technology that are outlined on the *MyScience* web site. When you have finished, check your understanding in the Types of Investigations drag and drop activity.

Brainstorming / mind mapping a theme

This is a key process in a *MyScience* investigation. It occurs in Teaching Phase 2, Preparation, and follows from students researching a topic area and leads to selecting an area of interest.

Brainstorming is a creative thinking strategy to generate ideas rapidly and without evaluation. Mind mapping is the process of showing the relationships between ideas. This combined process involves the students generating the ideas or topics that belong to the theme they have just been researching and the teacher 'thinking aloud' to model visual presentation of the relationships.

Primary students in the context of brainstorming and mind mapping around the theme of energy would often come up with quite different set of ideas and links to the one shown. They may include forces along with energy or omit or add several other types of energy. Students frequently blend the types of energy with sources of energy. The teacher's role is to question and prompt students using the context with which they are familiar, to elicit their ideas.

Types of teacher questions used in brainstorming/mind mapping:

- **Prompting** — Engaging students with the topic to draw our prior knowledge and understandings. 'Who can think of...?' 'What do you know about...?' 'What are some examples of...?' These questions are used extensively at the beginning of the brainstorming session.

- **Expanding** — Ensuring that the theme is expanded to provide more opportunities for students to find an area that interests them. ‘What are some other types of energy?’ These questions are often used in the early stages of brainstorming.
- **Clarifying** — Sometimes student suggestions are not clear. Clarification questions can help students communicate their ideas and prompt the ideas of other students. ‘What aspect of energy conservation are you interested in?’
- **Linking** — Eliciting links between ideas can make areas more relevant. ‘Is there a link between solar energy and plants?’
- **Analysing** — Some ideas can be analysed with the view to developing practicable investigations. ‘What are some ways that we use wind energy? How could we investigate the effects of solar energy on plant growth?’

Watch a group of students recount how they decided on a question for investigation.

Review your understanding of the types of questions to ask to promote the brainstorming of topics around a theme in this drag and drop activity.

A mind map should not be regarded as correct or incorrect, but rather as a reflection of the students’ current perceptions. The whole purpose of the exercise is to get students to find an area within a theme that interests them and that they would want to explore further through a scientific investigation.

TaLe ‘Student Research Project’ has advice for students starting to plan an investigation. Another link is to ideas for science projects.

Demonstrate your learning

For the theme that is to be used as a basis for the students’ scientific investigation, you will need to model the construction of a mind map that demonstrates the relationships between concepts and the theme. It is a good idea to first construct your own mind map and then discuss it with a colleague. Constructing a mind map is a good way to establish student prior understandings and so, the mind map you generate with your class may well differ from your own. Students are to brainstorm the topics through appropriate questioning, and you will develop a map that will show the relationships. The topics generated here will be used later in the Phase 2, Planning, of the *MyScience* investigation to help students generate ‘testable questions’.

Clarify your thinking about choosing a theme in this activity. If you want to build your confidence before brainstorming a theme to produce topics and eventually testable questions then try the Themes and Topics activity where you match the topic to the theme.

Knowing and Thinking Level 2

What is science?

Science refers to both the body of knowledge and the processes used to obtain that knowledge. Scientific knowledge attempts to explain the world around us based on evidence that is objective, rational, unprejudiced and accurate. Scientific processes involve making observations, measurements or collections of data about events or phenomena, seeking patterns, drawing conclusions, designing and conducting experiments. Scientific knowledge is often arbitrarily classified into branches or disciplines such as biology, earth science, the physical sciences (chemistry and physics) and astronomy or space science. Many scientific investigations and explanations are interdisciplinary.

Watch a scientist talk about how *MyScience* can engage students in the processes of science.

The Scientific Process and the metalanguage of science

The scientific method attempts to develop new insights and understandings or to integrate or correct previously held ideas. There is a range of terms that are used in science to describe the investigative process. In level 1 you were briefly introduced to the metalanguage of science. This section treats it more extensively.

The intentions of the scientific experiment or investigation are expressed as an 'aim'. The aim of an investigation is underpinned by an hypothesis. Scientists propose hypotheses as explanations of phenomena. An hypothesis is a proposed general explanation based on some understanding of the phenomenon being investigated. For example, when investigating the absorbency of paper towels two alternative hypotheses might be:

1. the thicker paper towel will be the most absorbent
2. the more expensive paper towel will be the most absorbent.

From the hypotheses predictions are made and experiments are designed to test the predictions. A prediction in this instance could be:

1. 'Thicko' has the thickest sheets of paper towel, so it will be most absorbent
2. 'Cheapo' is the cheapest brand so it will be the least absorbent.

Predicting scientifically — A distinction needs to be made about the difference between the scientific understanding of the term prediction and that used in everyday language. In the everyday sense prediction is a guess about what might occur. Astrology provides examples of non-scientific predictions. While predictions are often based on our past experiences, scientific predictions are based on understanding and logic related to cause and effect relationships. A scientific prediction follows an hypothesis which is a proposed explanation that is developed to describe an observation so as to relate two variables.

For example, an hypothesis could be that the harder you exercise, the faster your heart beats. This hypothesis is in the ‘If.... then....’ format. A well-worded prediction will suggest an investigation that is based on a fair test. The first part of an ‘If.... then....’ statement relates to the independent variable and the second part to the dependent variable. In the example, the heart rate depends on the exercise and not vice versa.

Scientific investigations need to be valid in their design. This means that one variable is deliberately changed, one variable is measured or observed to determine the results and that other variables are controlled. Any difference in results can be attributed to the variable that is deliberately changed. We often teach this idea through the mnemonic ‘Cows Moo Softly’. (Change one thing, Measure something, Keep everything else the Same).

Scientific investigations need to be repeated or replicated to ensure the results are reliable. We sometimes call an investigation that is both valid and reliable a ‘fair test’.

Conclusions are drawn on the basis of evidence. The evidence is often the result of a scientific investigation.

The results of science investigations lead to the development of scientific models, theories and laws.

Models, Theories and Laws in Science

A scientific model is a construct that explains an abstract or complex phenomenon and from which predictions can be made that can be verified. It can be a physical representation but it can also be mathematical. An example of a simple explanatory model for day and night would be the use of a globe for the Earth and a light source for the sun. The interplay of complex, varied and unpredictable events such as the weather are modelled with computers. Many scientific models are used to assist communication and understanding. Scientific modelling is also used to predict changes resulting from changes in atmospheric gases.

A scientific theory is an attempt to explain a phenomenon and that has substantial evidence from a number of experiments or fields that are all consistent. Scientific theories are not regarded as ‘facts’ but if contradictory data is obtained and verified, then the theory must undergo revision or be rejected. The Big Bang theory attempts to explain how the universe commenced; the Theory of Evolution through natural selection attempts to explain the diversity of life on Earth.

A scientific law is a statement of a relationship that can be verified experimentally (for example, Newton’s Second Law states that the greater the force acting on a given mass, the greater the acceleration of that mass). Scientific laws are regarded as facts.

The Scientific method

An internet search will provide you with copious information on the scientific method and key processes that are fundamental to scientific investigations.

If you want to read more about the processes of conducting an experiment, this web site may be of assistance.

An interesting discussion about the nature of science and common science misconceptions can be found at this web site.

You may like to become more familiar with the scientific language used when planning and conducting investigations. Here is a link to a glossary of scientific terms.

Link to a flow chart of the scientific method gives you additional information about the scientific process.

Test your understanding of the Scientific Method by matching the term to its definition in this activity.

Science as a Human Endeavour

Science and society are tightly interwoven. The draft Australian Curriculum: Science introduces a separate strand of learning for Australian primary schools of learning about the history, nature, practice, implications and career paths in science. The use of Scientist Mentors in *MyScience* provides an ideal way for students to learn about science as a human endeavour. A key goal of *MyScience* is to generate students' interest in science that is likely to initiate more serious consideration of careers in science, engineering and technology. The ultimate goal of the Australian curriculum is to produce citizens who can make informed, evidence-based decisions about current and future applications of science.

Some areas of Science as a Human Endeavour that you need to address include the changing nature of scientific knowledge and examples of how ideas have changed over time as our scientific knowledge has grown, how science has changed the way we live, how science has become so complex that often specialisation and collaboration are critical elements of scientific research. Students need to learn about the specific contributions of Australian scientists and the interdependence of science and culture on human choices.

Science in the media

Modern media provides excellent stimulus for engaging students in scientific topics and issues, integrating the use if ICT into teaching and learning and developing deeper knowledge of science concepts. Issues such as global warming, sustainability and the ideas that underpin technological developments can all be explored. A good starting point is ABC science. Another option is Scope

Demonstrate your learning

Apply knowledge of fair testing to discuss the methods used by Australian scientists such as Barry Marshall and Robin Warren who changed thinking and our understanding of the cause, and hence the treatment of stomach ulcers. Use ideas generated from sustainability issues that are discussed in the media to jointly construct fair test investigations, for example, use of materials to better insulate homes.

Model the use of scientific language in the classroom when investigating scientifically and discussing scientific issues. Plan and conduct a lesson in which scientific language is explicitly taught.

Planning Investigations Level 1

How do I help students to plan their investigation?

Watch two students explain the best thing about doing a science investigation.

Watch a parent give her perspective.

Planning is essential for students to conduct successful scientific investigation. After the class theme has been expanded and topics for investigation explored a testable question must be finalised. This adds greatly to the ownership and motivation of students, but can be difficult to achieve. Mentors support this process. Students will also need to learn about what constitutes a 'fair test' and how to plan an investigation based on controlling the variables — ensuring that the scientific investigation will achieve valid results. Sources of error and the need for replication or repetition need to be considered to achieve reliable results. Planning involves the students listing equipment and a procedure for the investigation. Finally, safety checks for any chemicals used have to be carried out by the teacher.

Watch this experienced teacher discuss some of the practicalities of choosing testable questions.

View this PowerPoint presentation about Planning Investigations.

Clarify your understanding of the sequence of activities that you undertake when planning and conducting a *MyScience* investigation.

Reinforce your ideas about why you should conduct investigations by completing this Plus/Minus/Interesting table.

Clarify your understanding about processes in planning an open investigation in this cloze passage activity.

Read more on the benefits of working scientifically in the Mark Hackling article on Working Scientifically.

Demonstrate your learning

The following table references a number of science investigations. Go to the sites or follow the links and check each investigation. Check the safety requirements of your system to see if the activity is suitable for the year that you teach. Check with your latest science curriculum to see if it is a suitable activity for the year you teach. Does it represent an example of an activity that is a 'fair test,' a 'design and make' activity or is it more suitable for using models, information research, surveys or data from secondary sources or perhaps is it a combination?

Example	Type of activity
Class builds a scale model of the solar system	
ABC Science, 'Elephant's toothpaste'	
TryScience 'Lung Capacity'	
ABC Science, 'Catchment Detox'	
ABC Science, 'Mobile Phone disco'	
TryScience 'Aluminium boats'	
SunSmart Millionaire 'Different materials'	

Check your answers.

Example	Type of activity
Class builds a scale model of the solar system	This is really a number of methods of investigation. Students need to access data from secondary sources, complete a 'design and make' activity to construct a model.
ABC Science, 'Elephant's toothpaste'	This is really just a teacher demonstration, not an investigation. It could be used to emphasise the need to follow safety procedures. There is no design element in the investigation, just a 'make' by following steps. It could be modified by varying the quantities of yeast, detergent or the size and shape of the bottle. You could even test other foods (liver and potato also work) to see if they produce the same effect.
TryScience 'Lung Capacity'	This is a 'make' activity that could be turned into a 'fair test' investigation – 'Do boys have a larger lung capacity than girls the same age and size?'
ABC Science, 'Catchment Detox'	This is a simulation that is really based on 'using a model'. A model does not have to be a physical representation, but can be represented as a game, a formula, an analogy or visually.
ABC Science, 'Mobile Phone disco'	This is an activity to make a model of the ear drum. Students could also do information research about properties of different sounds and then see if they can use the model to test predictions.
TryScience 'Aluminium boats'	This activity is a 'fair test' in that the only difference between the two situations is the shape of the aluminium foil holding the coins. Results are hardly unpredictable.
SunSmart Millionaire 'Different materials'	This activity is an example of a 'fair test'. The time the beads take to change colour is measured (dependent variable), the different materials are the independent variable and everything else is kept the same.

Planning Investigations Level 2

What are the expectations of my students for investigating scientifically?

The draft Australian Curriculum: Science outlines a continuum of learning across the years as students progress their ability to plan how to investigate scientifically. Key points are that:

- From years 1 and 2 students are developing the following inquiry skills: exploring, posing questions, making inferences and predictions, working safely using familiar equipment, manipulating materials and making observations and measurements with informal units. They use their observations as evidence and reflect on methods.
- From year 3 and 4 students have expanded on earlier skills to also be able to recognise a fair test, collaboratively plan and conduct a range of investigation types, use appropriate materials, tools and equipment.
- In years 5 and 6 students are expected to be able to identify a simple question that can be scientifically investigated, predict the outcome, contribute to decisions about the most appropriate investigation method, identify risks and select and safely use equipment and use a range of tools to observe and measure.

Read a detailed treatment of 'Working Scientifically – Implementing and Assessing Open Investigation Work in Science' by Mark Hackling found on the *MyScience* web site.

Review your understanding of this article in the 'Working Scientifically' quiz.

If you would like to read more about teaching scientific inquiry and posing 'testable' questions, follow this link.

'Testable' questions

Aside from the practical issues and three criteria for 'testable' questions, there are other considerations when determining if a question that students pose can be scientifically investigated.

Criteria for 'testable questions'

- Is it a question to which I do not already know the answer?
- Is it a question that I will be able to investigate in my school/classroom within the required time?
- Is it a question to which I want to know the answer?

A very useful guideline it to try to convert the question into the format of 'What is the effect of.... on.... ?' Note that a 'testable question' is closely related to an hypothesis.

The list of questions in the activity below, posed by students, shows that a high percentage of questions suggested by students need to be clarified or modified to be able to be used in an investigation. The use of science mentors can be a great assistance to cope with the logistics.

If you want to test your understanding, do the matching activity where you link topics to questions.

Read more about the use of questions to design investigations. There is an excellent link to Understanding Scientific Inquiry.

Can you identify which of these questions are testable? Stage 2 questions on Energy, alternatively, Stage 3 questions on Disasters. Use the quiz to check your answers with the suggested answers and comments.

Demonstrate your learning

Get students to brainstorm a list of 'testable' questions from the topic they developed in earlier mind mapping activities. Use explicit roles in groups to get student groups to refine their list of 'testable' questions. Invite scientist mentors into the class to help with the final selection of a testable question for a scientific investigation. Get students to develop a list of appropriate equipment for their specific investigation and record a procedure to outline the steps to be undertaken after consultation with their mentor. Evaluate and give feedback on safety rules generated by students for their specific investigation.

Check your understanding of 'fair testing' in this quiz.

Conducting Investigations Level 1

Tips for conducting investigations

Conducting investigations is the domain in which scientific investigations are physically carried out; where observations and/or measurements are made and recorded. In Teaching Phase 1, Practising, of *MyScience* students perform verification and guided inquiry investigations by following the same hands-on procedure and the class then jointly analyses the results to draw conclusions from the collected data. Emphasis should be on the skills of accurately measuring or observing and recording. By the end of primary school *MyScience* students should be independently planning investigations so that, within a class, several different investigations may occur simultaneously – with students working in groups of twos or threes. Many teachers find the use of scientist mentors invaluable when conducting open student-driven investigations. Aspects of resource, equipment and time management, group roles, safety and classroom management are often major considerations in this domain.

Some teachers find role badges effective to support classroom management. If a group member is designated as the 'communicator' then only he/she can communicate with the teacher or other groups. The group must meet first, discuss the issue and if they want further clarification, only the communicator can proceed to the other groups or teacher. This means that a teacher may deal with a query a maximum of seven times rather than twenty eight. Other teachers have students wear coloured adhesive dots to indicate roles. The teacher writes the description of the role that matches the colour on the board. This allows some flexibility of roles depending on the investigation or activity.

The TaLe web site has a resource called 'Student Research Project' that is written for high school students, but many primary teachers may find the sections on planning and collecting data useful. In planning there is advice about risk assessment and an activity in which students scroll over a laboratory scene to identify hazards. Under 'collecting' useful sections include 'observation' and 'more data' for advice about quantitative and qualitative data and use of photographs and recordings.

Reasons for conducting investigations

Watch the enthusiasm and confidence of these students as they briefly report the results of their investigation.

Hackling quotes teachers giving the following reasons why they conduct hands-on investigations:

Knowledge and Understanding:

- concrete experience of natural phenomena
- experiencing and developing an understanding of the nature of science
- conceptual development.

Skills:

- language development
- developing investigation and problem-solving skills
- developing techniques and manipulative skills associated with using scientific equipment
- learning to work cooperatively.

Attitudes:

- motivation and enjoyment of science
- stimulate curiosity and creativity.

MyScience wholeheartedly endorses that learning science by actually doing hands-on investigations efficiently and effectively addresses science understanding, skills and attitudes.

Hackling (2005, page 14) quycaillyotes teachers identifying the following barriers to conducting open investigations.

Barriers to conducting open investigations:

- crowded curriculum
- investigative skills not recognised in traditional assessments
- students need set procedures
- classroom management, equipment, safety.

Hackling addresses the later two issues by providing scaffolding tools to assist teachers and students to plan and independently carry out investigations.

Demonstrate your learning

Select a science investigation and conduct it with your class. Ensure students work in groups and they are allocated roles and wear role badges. Carefully plan the equipment and resources you need and conduct a pilot of the investigation to ensure that it provides a valuable learning activity for students. Groups reflect and evaluate their collaborative processes making suggestions for improvement.

Conducting Investigations Level 2

How can I use scientist mentors effectively in my classroom?

Watch an experienced teacher and a student talk about the value of mentors.

Mentors serve a dual purpose. Firstly, the extra bodies and sets of eyes are a key to synchronously conducting diverse investigations safely and efficiently. (Note: some teachers who cannot access the required number of mentors make use of staggered investigations so that each mentor may work with a number of groups of students to plan and conduct the investigation.) Most importantly, mentors can help student groups select a testable question that is practically suited to the demands of school classrooms and equipment and they can provide examples of current areas of science and career paths. As scientist mentors talk about their daily activities, students gain insights into career paths that may suit them and their interests. Scientist mentors help teachers address many of the content within Science as a Human Endeavour.

It is important that you communicate effectively with your Scientist Mentors. This could be by telephone or through a number of online methods such as email, wiki etc... Many mentors will have not been in a primary classroom since their own childhood days. They may have little understanding of the capabilities of your students, how primary schools/classrooms function, the types of science investigations that are 'doable' etc. This applies as much to setting the bar 'too low' as it does to setting it 'too high'. Mentors will need guidance as to what to do when they first arrive at your school (where to sign in), how students should address them (first name... ?, Mr Smith... ?) etc. They need to know that the investigations that they are supporting are student centred/directed, that they should ask students open-ended questions that encourage problem solving. Mentors typically do not need to be forewarned of student behaviour issues since the type of learning experiences afforded through mentor involvement frequently lead to students being engaged and interested. As mentors meet and communicate with your students listen carefully to the types of science related questions that they ask – they could provide useful information for you as well. Offer your mentors information sources about the topics that students are investigating so that they better understand students' reading and comprehension levels.

Another mentoring option that has worked particularly well in one *MyScience* hub is the use of MyStics who are year 9 and 10 students or *MyScience* Trainees in the classroom. This provides the opportunity for reciprocal learning and support in a buddy environment. They work in addition to scientist mentors and provide great benefits in transition to high school from many students. MyStics tend to be used after *MyScience* has become an accepted part of the school culture. Another mentoring option is the use of secondary teacher science undergraduates. In some cases even teachers from neighbouring high schools and laboratory technicians have been successfully used as mentors. These again provide reciprocal benefits but they are different from those of using career scientists.

CSIRO Scientists in Schools has information for teachers about how to use scientists in their classrooms.

The Australian Government Quality Teaching Program provides advice and support for the process of blogging using Edublog or go to this site.

How can I teach students to measure accurately?

Length

Rulers, tape measures and trundle wheels are suitable, depending on the length being measured. It may be possible to get your scientist mentor to bring in vernier calipers or a micrometer to show how very small distances can be accurately measured.

Key points to focus on when measuring length are:

- Ensure that students carefully align the object being measured with the ruler and their eye that is. ensure that they are all in a straight line. When measuring each others' height students need to be elevated or bend their knees so as to get their eye, ruler and top of the subject's head aligned.
- Have students tabulate results to illustrate the variation in readings when taken from different angles that is. when eye, ruler and object are NOT aligned.

Volume

Volumes of liquids can be measured in measuring jugs and cups. Rain gauges can be used to practice measuring liquids with a scale.

Measuring cylinders, because of their shape and scale and the way they have been carefully calibrated can give more accurate measurements of volume than everyday items such as measuring jugs. The volume of small, irregular solids can be obtained by how much water is displaced when it is submerged in water. This type of method is frequently used when measuring lung volume by students expelling the air in their lungs into a large inverted container full of water.

To record the volume of an irregular solid, firstly record the volume of a liquid in a volumetric container and then add the solid. The volume will increase by the volume of the irregular solid. Alternatively there is the 'overflow' method. Students can measure the volume of their hand by immersing their hand in a full container that has a device to collect the overflow. The volume of the liquid that overflows is the same as the volume of their hand. (Read 'Mr Archimedes' Bath' by Pamela Allen)

Students can investigate error in measurement of volume by adding 20 x 5 mL teaspoons of water to a 100 mL measuring cylinder. The fact that the reading is not exactly 100 mL is a reflection of how small errors, if repeated, will have an impact on accuracy.

Mass/Weight

Scientists distinguish mass from weight. Mass is the amount of matter, measured in kilograms (kg) and is a constant throughout the universe. Weight is the force on that mass that results from gravity and is measured in newtons (N).The weight of an object will vary with the strength of gravity. You will weigh less in the low gravity of the moon that you do on earth, but your mass remains the same.

In everyday non-scientific language we talk about an object's weight (for example, 1 kg of sugar) when in fact we are referring to its mass. One kilogram of sugar actually has a weight of 9.8 N on Earth.

We measure mass using a balance (like the justice scales) where exact masses are placed until a balance is achieved. Generally for primary students, using bathroom and kitchen scales that record a mass are sufficient.

Time

Time is an ideal dimension for discussing digital versus analogue measurements. Students can use a range of clocks and stop watches depending on the required accuracy of the measurement.

Students will need to be taught how to read and record digital time measurements. Even young children are able to do this although their conceptual understanding of tenths and hundredths of seconds is likely to be underdeveloped.

As timing of short time intervals with a stop watch depends on reflexes, errors can be significant. It is important to pilot investigations and look at the variation of results. If students are measuring how long it takes a ball to fall through a specific distance, there can be errors in both starting and stopping the stopwatch. A pilot investigation may suggest you need to modify the procedure for example, drop the ball from a much greater height so that variations in results are not significant compared to the overall reading.

How do we ensure reliable measurements?

Errors are a natural part of measurement. Errors can be minimised by taking a number of measurements and calculating the mean (average).

Replication

Some activities result in the 'destruction' of the items being measured. If you are germinating seeds, at the end of the activity you no longer have seeds, but seedlings instead. You therefore cannot repeat the activity with the original seeds, so instead you replicate it by doing the activity with a large number of seeds in the first instance. In addition some activities use things that have a great deal of natural variation. Living things, as the subject of investigations often pose this problem. If you want to test the effectiveness of a sport drink, you need to replicate the activity over a large number of students. Results for the seedlings or students are averaged.

Repetition

If you are measuring how high a ball rebounds, you can safely repeat the activity and take a number of measurements. Repetition of measurements can reduce error and increase accuracy.

Reliability

An activity is considered reliable if it can be repeated or replicated and still achieves the same result.

For scientific research to be accepted, it must be presented in such a way that peers can replicate it and establish that the results are the same.

Demonstrate your learning

Conduct science investigations with the class that require at least two different attributes are to be measured accurately. As a class, collate results and discuss evidence for the accuracy of the recorded measurements.

Processing Investigations – analysing and concluding Level 1

Watch what teachers have to say about developing literacy and numeracy through *MyScience*.

The domain of processing data by analysing it and drawing conclusions involves students transforming and manipulating their recorded data to make valid deductions. Results are related to the original question and aim of the investigation to draw conclusions. These processes involve numeracy skills such as data organisation into tables, calculations including averaging, and construction of graphs to better enable identification of patterns or trends and relationships between variables.

What are the expectations for data analysis for the year I teach?

The following table summarises the position of the draft Australian curriculum: mathematics with regard to teaching of statistics (data) for years 1-7.

Continuum of data representation skills

Year	Expectations
1	• Use or construct simple pictographs • Identify links between lists, tables and pictographs
2	• Use tallying to record data and construct tables, pictographs and bar and column graphs • Use lists, tables and graphs of simple data to attempt to interpret and explain • Identify that information remains the same even though representations may change
3	• Make predictions, carry out investigations about familiar situations to gather data and report the results • Make and use tables, diagrams and graphs, including dot plots that have prepared baselines, and identify the links between them • Understand the importance of scale and equally spaced intervals on an axis

Year	Expectations
4	• Generate questions and use surveys to obtain data and use the results (including the use of ICT) to answer questions • Use ICT while constructing, reading, interpreting and identifying links between tables and simple graphs that contain more complex relationships between data and symbols • Identify how a small sample size impacts on outcomes of data compared to larger numbers in trials of chance events using ICT
5	• Collect data over time to carry out an investigation into the relationship between variables, report results draw conclusions and justify them • Begin to explore bivariate data over time (for example, identify that comparison of the growth of pea and bean plants over several weeks requires that points be plotted on identical axes) • Use lists and dot plots to identify the mode and median • Analyse and compare a range of data representations for specific situations
6	• Construct, read and interpret tables and graphs including ordered stem and leaf plots, and construct pie charts and other simple data displays including using technology • Analyse data in the media and elsewhere for misleading representations that may result from sampling a population • Use repeated measurements to explore variation and error
7	• Use ICT and compare data sets using mean, median, and range and show reasoning • Collect univariate and simple bivariate data and use of back-to-back stem plots and scatter plots to investigate questions

An in depth discussion of 'The Development of Graph Understanding in the Mathematics Curriculum' can be found on this NSW DET link. Not only does this link provide information on the history and background of graphing, the role of technology, the development of graph interpretation and creation but it also gives excellent examples of types of graphs and their relationships.

For years 3-6 the draft Australian curriculum: mathematics suggests:

'These years focus on the importance of students studying coherent, meaningful and purposeful mathematics that is relevant to their lives. Students still require active experiences that allow them to construct key mathematical ideas, but there is a trend to move to using models, pictures and symbols to represent these ideas.'

This strongly implies that the approach of *MyScience* aligns closely with the curriculum intentions of dealing with real, meaningful data and using graphical methods to represent and interpret the data.

MyScience investigations provide an authentic context for the collection of data to address the demands of the year 5 and 6 draft Australian curriculum: mathematics. *MyScience* students are usually performing 'fair test' investigations looking at the effect of one variable (independent) on another variable (dependent). For example, students may investigate the effect of light on the preferred hiding spots of slaters. They may set up a shoe box containing slaters that has a well-lit area and a dark area. The setting up of light and dark places provides the independent variable, and the counting of the numbers of slaters at each location is the dependent variable. Data obtained by this type of investigation is called bivariate data. If you want to learn more about univariate and bivariate data, it is concisely summarised in a table at this link. Univariate data is based on data that describes, such as the number of students in year 5 at a particular school. Bivariate data is data that tends to explore relationships and cause-and-effect. Note that this draft Australian curriculum: mathematics indicates that by year 5 students should begin to explore bivariate data that has been collected over time. This is a simple example of bivariate data. The independent variable (the one that is deliberately changed) is actually time and the dependent variable is measured to give the result. An example might be describing the growth of a plant in terms of its change of height over time. This activity is descriptive over time but does not constitute a fair test. A *MyScience* investigation might look at the effect of fertiliser on growth of plants. Now the independent variable becomes use of fertiliser and the dependent remains the height of the plants. This is an investigation based on the collection of bivariate data, but in addition, students will often collect their data over time to get a better understanding of when in the growth of plants that the fertiliser may have the greatest effect. Graphing such results would involve putting time on the horizontal axis, height of plants on the vertical axis and two sets of data plotted and joined by lines to represent the plants grown with fertiliser and those grown without.

In primary school, it is expected that students will have dealt with data collected around one variable (univariate) for example, the height of students in the class, the age of students at a school and processed it. Data representations include pictographs, bar and column graphs, ordered leaf and stem plots and dot plots. In a *MyScience* investigation the data is likely to be bivariate and represented as bar, column, scatter plots or line graphs.

What are the main components of a table?

Tables are made up of intersecting rows and columns. The title identifies the nature of the data and the column and row headings identify the variables being related and may also give the units, so that they do not have to be repeated in cells. In a *MyScience* investigation, the table may have sufficient columns to allow for the recording of data over a number of trials and so have sufficient space for the final calculation of the mean. The following is an example of a table that could be used for the previously described investigation into the preferred hiding places of slaters.

Effect of light on the preferred hiding place of slaters

	Number of slaters			
Type of hiding place	Trial 1	Trial 2	Trial 2	Mean
Lit area of shoebox				
Dark area of shoe box				

Younger students may use the structure of a table for tallying results and then presenting the final count. Stem and leaf plots use a tabular structure to represent numerical data and are commonly introduced in year 6. They contain at least two columns, one, the stem contains the place value of data. The adjacent 'leaf' column combines with the stem data to give the actual numerical value. Definition and identification of the uses of stem and leaf plots with examples is contained at this link. Stem and leaf plots are useful for larger data sets. While retaining a table format, ordered stem and leaf plots give some visual representation of the frequency of some of the groups of data. From an early age, students need to learn about the connections between data in tabular form and graphical representations. As students progress, the examples of the data and forms of graphical representation become more complex and explicit teaching of advantages and disadvantages of various data representations is required.

How do we calculate averages?

The draft Australian curriculum: mathematics indicates that by year 5, students should be able to understand and apply the concepts of median and mode. The median of a data set is the middle value, whereas the mode is the most frequently recorded value. These can largely be determined from visual representation of the data in graphs such as dot point graphs or leaf and stem plots. By year 7, students need to be able to calculate mean values from numerical data. The mean for a data set is obtained but summing the data values and dividing by the number of values recorded.

Example of averages calculation

Ten students scored 25%, 31%, 42%, 42%, 51%, 57%, 63%, 68%, 71% and 75% in a test.

Record this data in a stem and leaf plot

Data recorded in stem and leaf plot

Student % results in a test	
Stem	Leaf
2	5
3	1
4	2,2
5	1,7
6	3,8
7	1,5

Calculation of median

When there is an odd number of scores the median is the middle value. In this case there is an even number of scores with the middle two being 51 and 57. The median becomes (51+57) divided by two or 54.

Calculation of the mode

The mode or most frequent score is 42. It can be easily seen from the stem and leaf plot as it is the only score that is recorded twice. If all scores had only been recorded once there would be no value for the mode.

Calculation of the mean

Add the scores and divide them by the number of scores.

(25+31+42+42+51+57+63+68+71+75) divided by 10= 52.5

What type of graph will we use to represent the data?

Data relating to one variable can be represented as pictographs, bar and column graphs, ordered leaf and stem plots. Dot plots are also useful to represent data for relatively small data sets. These types of data representations help to demonstrate the range of data including gaps, clusters, outliers, mode and, to some extent, the median. Pie charts are useful to represent the relative or proportional composition of a total amount, but have limitations when the components are numerous and/or represent small portions of the whole.

The type of graph that is generated from the data depends on the type of data. In 'fair test' investigations students are investigating the relationship between two variables (that is. bivariate data).

For more advanced students you could distinguish continuous from discontinuous data. Discontinuous data is information about a characteristic that an object either possesses or does not possess. Blood type (either O, A, B or AB), year of birth or gender are discontinuous data sets. Each option is discrete and needs to be represented as such. Discontinuous data is usually represented in a column graph (vertical columns), bar graph (horizontal columns) or pie chart.

Continuous data is information about a characteristic that can be represented numerically and varies continuously such as height, weight, hand span, performance in a timed task. This type of data is often represented on a scatter plot or line graph. (see Integrating ICT learning pathway 1 for more information on how to use Excel to create such a graph). Once the graph has been constructed it can be used for interpolation or extrapolation (see level 2 pathway). The line constructed in a line graph does not necessarily join all the points, but usually is a 'line of best fit' indicating the general trend in the relationship. If there is no apparent relationship, the points may be represented as a scatter plot. Scatter plots can be used when the data set is really large, such as graphs of state-wide student test scores or size and brightness of stars.

Graph protocols

Most graphs have two axes – an x-axis (horizontal and represents the independent variable) and a y-axis (vertical and represents the dependent variable). Sometimes you may use several data sets on the one graph. If you are investigating the impact of fertiliser on plant growth, the x-axis may not represent fertiliser/non-fertiliser but time over which the data was recorded. Two sets of points (often with a key or in different colours) are plotted to help demonstrate the impact of the fertiliser. It may show that initially the fertilised plants grew faster, but that the impact gradually reduced.

A common mistake when constructing graphs is for students to place the data points along the axes at equal distances rather than to scale. For instance, data recorded at 1 minute, 5 minutes and 15 minutes would be equally spaced along the x-axis. The resultant line between the plotted points will therefore not truly represent the relationship.

TaLe 'Student Research Project' has a section on graphing and tables (collecting data).

Learn more about the processes of tabulating and graphing data from this University of Tasmania web site.

This web site has a tutorial on the use of Excel for graphing.

If you want to learn more about numeracy teaching and learning the National Literacy and Numeracy Week web site has a wide range of resources such as 'Critical Numeracy in context' a seven minute video by Dr Jane Watson from the University of Tasmania.

Analysing data

From the hypotheses in the following table, make predictions about the data if:

- The hypothesis was true.
- The hypothesis was not true.

Hypotheses

Hypothesis	Prediction if my hypothesis is true	Prediction if my hypothesis is not true (null hypothesis)
The thicker the kitchen paper, the more water it absorbs.	Paper A is thicker than paper B which in turn is thicker than paper C. Paper A will absorb more water than paper B than paper C.	Paper B or C will absorb as much water as, or more than, paper A.
The rougher the surface, the hotter it gets when it is rubbed.	Surface A (carpet) is rougher than surface B (lino) than surface C (polished wood). When you rub your hand back and forth five times on surface A it will get hotter than surface B, which will get hotter than surface C.	Rubbing surface B or C, my hand will get just as hot, or hotter, than rubbing surface A.
Colder water freezes faster than hot water.	Container A contains water from the hot tap and container B contains water from the cold tap. When put in the freezer, the water in container B will freeze in less time than water in container A.	
Vinegar cleans a coin faster than a soft drink.		
Girls have a better short term memory than boys.		

Demonstrate your learning

Distinguish median, mode and mean and explain why the term ‘average’ needs qualification.

Plan and explicitly teach a lesson on data analysis and graphing to address the skills students will need for the processing of science investigations.

Deconstruct examples of drawing conclusions from data sets collected in science investigations.

Processing Investigations – analysing and concluding Level 2

Watch what teachers say about developing literacy and numeracy through *MyScience*.

After tables and graphs have been constructed, students need to analyse data to identify patterns or trends. This can be scaffolded by working with data (preferably first hand data collected by students) as a whole class. An important part of this process is the critical analysis of the data.

Students need to go back to their original hypothesis and prediction and compare the actual data to the prediction. An issue that may arise is that there is no clear pattern or trend in the data, or that there are contradictory data that does not support the major pattern. There is also the question of whether the amount of difference observed is sufficient for the result to be statistically significant — though this is often not an issue emphasised with most primary school science investigations. An example might be as follows:

Most students in the group have improved their beep test results after drinking a sport drink, but some have actually recorded worse results. A problem could be that the sample size of the data is too small. Maybe a small number of worse performing students have skewed the data. This investigation needs to be completed with several classes in each grade and the results then averaged before analysis.

SunSmart Millionaire has an excellent section on replication and repetition necessary for reliable data. 'The Lab' from this resource also contains information about accuracy, reliability and validity of data from investigations.

How do I teach students to critically analyse their data?

Watch a group of students discuss their investigation into the effectiveness of a sport drink and note the issues that arise in the analysis of their data.

Here is a set of questions to give students as they independently analyse their results. The answers to these questions will indicate the reliability of the data and therefore the degree of certainty with which a conclusion can be drawn.

1. Is the data consistent or is there a set or single piece of data that is not consistent with the remainder of the data? As much as students may wish to, unusual results are part of the data set and DO need to be included. Maybe a few more trials could be performed to see if the variations continue.

2. How large are the variations compared to the overall size of the data being collected? If students are measuring crater diameters that are in the vicinity of 2 cm, is the variation more or less than 0.5 cm? that is. do the majority of readings fall between 1.5 and 2.5 cm? Are there any outlying results and what might be the cause of these? Are the measurements being taken with extreme accuracy? The sloppier the measuring, the more likely there will be variations. Were the measurements always taken in the same way..., by the same person...? Were there any variables that may not have been satisfactorily controlled?

Issues in student's table of results

Hackling 'Working Scientifically' (2005, page 23) provides an annotated work sample of an investigation by a year 6 student, including the results presented in a table. If this was the work of one of your students, what issues would you like to explore further?

Answer

The large range in data of each trial suggests that more trials should have been conducted. Also as the data was collected to the nearest integer (whole number), reporting averages to decimal places is suggesting a level of accuracy that is beyond the data.

Interpolation and extrapolation

One major source of errors in student investigation is the lack of an adequate data set in terms of the range and number of samples of data. (See 'Conducting Investigations' level 2 learning pathway for a treatment of the need for replication or repetition to ensure reliability of data). For example, if students are investigating the impact of drop height on the diameter of the impact crater, they may need to have selected more than two heights from which to drop the object. Not only does there have to be a sufficient number of samples, but the range over which the object is dropped has to be sufficiently large. Four sample heights at 1.0 m, 1.2 m, 1.2 m and 1.3 m may be an adequate number of samples, but they may be taken over too small a range. For many students their accuracy of maintaining these height differences and measuring small differences in crater diameter may mean that results do not show any noticeable differences.

Making generalisations

A key concept to teach students in data processing and concluding is that care is necessary when going beyond the specific results and conclusion of an investigation to discuss the more general implications. For example, it would be easy to make the generalisation that sea levels will rise as a result of the land ice melting and entering the ocean because of global warming as a result of a simple investigation measuring water levels as a large 'land based' ice block melts in a tub of water. Actual data suggests that a major cause of sea level rising as a result of global warming is thermal expansion of water. This is due to the behaviour of water as it warms above four degrees Celsius. The point is that in the real world many factors come into play that are not present in simple controlled experiments, and to make sweeping generalisations from such data is not a good idea.

Re-visiting the theme around which the investigations were planned

It is most important to return to the initial brainstorm/mind map of the theme into topics and collate the conclusions made across the class. This completes the learning cycle that commenced in the 'Knowing and Thinking' pathways and enables students to see how their results tie in with the class topic for example, energy. Students need to understand the science underpinning the reason for their result so that they are able to clearly articulate the WHY of their findings. An example would be that an increase in temperature (increasing the amount of heat energy) causes solid ice to change to liquid water which then runs into the ocean, thus raising the sea level. The amount of heat energy influences the rate of melting.

Demonstrate your learning

Conduct a class discussion that relates the findings of the scientific investigations of all of the class groups to the overall topic and theme.

Explore with the class what investigations could be further explored to add to their understanding of the topic or theme.

Reflect on your teaching of a science investigation and, in particular the data analysis, and make a list of improvements you would make next time.

Processing Investigations – explaining and publishing Level 1

Watch what teachers say about developing literacy and numeracy through *MyScience*.

The domain of 'processing' the investigation by 'explaining and publishing' the investigation involves students presenting or reporting their investigation and occurs simultaneously with the domains of knowing and thinking, evaluating and integrating ICT. Students may return to their original mind map to represent how their investigation has added to their knowledge and how applications of their investigation may impact on individuals, society or the environment. The presentation of a scientific investigation requires literacy skills and may also involve the use of multimedia and consideration of the audience of the published work.

Read a detailed account about Scientific Reports. This web site also has links to other excellent sites that support writing lab reports for teachers.

Investigation reports

An investigation report is really a composite text. It starts with a statement of the AIM which is really just a re-wording of the original hypothesis for example, Hypothesis: drinking a sport drink will improve performance in a beep test, AIM: to find out whether performance in a beep test is improved after drinking a sport drink. The METHOD is an example of a procedural text – where equipment is listed and the steps listed. Diagrams are frequently used to clarify the set-up of equipment. RESULTS are usually expressed in a table and graphed (see the section – Processing Analysing and Concluding) or as a report and the CONCLUSION may contain the explanation. More sophisticated investigation reports will include a discussion/justification (exposition or discussion text types) of the method. This may include suggestions about how the investigation could be made more valid or reliable. For example, inconsistency in results may be due to the many variables that cannot be controlled when working with humans as subjects in an investigation or human error.

View the work sample on the Board of Studies ARC web site including a procedure for filtering muddy water.

How to write procedures

The main rules in writing a procedure (method) are:

1. Start with a list of equipment.
2. Write steps as a numbered list.
3. Write steps in the order that they are carried out.
4. Commence each numbered point with an active verb. Sometimes an adverb such as carefully, slowly can be used with the active verb. Any qualification to the step can follow the first sentence that gives the clear direction.
5. Use simple present tense for the verbs.

6. Use an instructional style in second or third person that is. 'we collected the equipment' should read 'collect the large tub, stopwatch and aluminium foil'.
7. Write the heading as a statement of the aim of the scientific investigation.

How to complete scientific diagrams in the procedure

A labelled diagram showing how the equipment is set-up is frequently used to support the communication of the procedure. The rules for constructing hand-drawn diagrams in science include:

- draw in pencil as a single line with no shading or colouring
- where there are straight lines, use a ruler
- label parts with a clear line drawn to the relevant part
- diagrams should be drawn to approximate scale
- diagrams are drawn in two dimensions not three.

Primary students may have difficulty addressing all of these rules, but the main criterion is that they have communicated accurately. Students may be encouraged to take digital images of their equipment and then manipulate the image to add labels. A work sample from the Board of Studies Assessment Resources Centre web site shows a typical example of a primary student's scientific diagram.

How to write explanations

1. Start with an introductory paragraph introducing the phenomenon being explained. It could include a definition or a brief description.
2. Include technical and scientific terms.
3. Use action verbs in simple present tense, an impersonal style in second or third person.
4. Make use of conjunctions such as – as a result, because, before, how, if, once, since, than, that, though, till, until, when, where, whether, while.

In the write-up of a scientific investigation, an explanation may be included as a few brief sentences outlining what was done to ensure that the investigative method was as valid or reliable as possible. An explanatory text may also be used to convey the background research and provide a reason why the topic for investigation was initially selected. The explanation may also address the result, conclusion or hypothesis. For example, 'The harder ball bounced higher because it lost less energy when it hit the surface.' 'The experiment was valid because all the variables were controlled except the one that we deliberately changed. We repeated our measurements four times and took an average so that our results were reliable.'

The Board of Studies has an Assessment Resources Centre (ARC) that contains annotated work samples. This link is to an explanation on how a simple electric circuit works.

How to write discussions

A discussion, as part of an investigation report, demonstrates student learning about the method used in the investigation including validity and reliability, the aspects that were good and the aspects that may have been improved. The discussion usually includes an explanation of what has been found – the results – and how these relate to current understandings about the phenomenon being investigated.

The 'evaluation' part of an investigation report demands higher-order thinking and may be quite challenging for students to complete at anything above a superficial level. A concluding statement usually completes a discussion.

The Board of Studies Assessment Resources Centre (ARC) web site has an annotated student work sample of a report in which the student has reflected and suggested improvements on an activity to make an electric fan.

Demonstrate your learning

Explicitly teach the language and text types required for students to communicate all aspects of their science investigations.

Develop a set of learning criteria so that students have clear expectations of the requirements of their presentations of their science investigation. Apply these criteria to develop a means of communicating constructive feedback to students and parents.

Processing Investigations – explaining and publishing Level 2

Watch what teachers say about developing literacy and numeracy through *MyScience*.

Science fairs and celebration of learning

One of the key elements in *MyScience* is the celebration of learning. This often occurs through a Science Fair event at the school with a goal of allowing students to share their knowledge and understanding with a range of listeners, and at the same time serves to raise awareness of the importance of science education within the school community. Students initially 'publish' their work as posters, demonstrations, oral explanations or other formats, which are displayed in the Science Fair and from there, teachers may select some to be entered into other competitions and awards schemes run at state or even national level. Within Australia these include awards schemes run by state and territory science teacher associations such as the Young Scientist Awards, the CSIRO CREST award scheme, the BHP Billiton Science Awards and even the Australian Museum Sleek Geeks Science Eureka Prize (go to the 'What?! A mountain blows its top off' for an example of effective communication or this link to 'Why does ice float?')

Oral presentation of a scientific investigation at a science fair with all the attendant planning and recording means that students often grow in confidence and expertise. Students will recount their activities, justify their choices and select appropriate media (poster, digital and/or video images) to provide evidence and engage the audience. The publication of an investigation report and its presentation at a science fair provides an ideal way to address the increasing emphasis of curricula on multimodal presentation of information. Modes of language include reading, viewing, writing, creating, speaking and listening. Multimodal texts combine, for example, print text, visual images and spoken word as in film or computer presentation media.

Science fairs often provide the challenge of communication with a varied audience. If junior students and young siblings are involved, concrete demonstrations will help the audience to understand the procedures and the nature of the results. Students will experience the increased engagement of the audience through active participation. Presenting students could be encouraged to showcase their investigations both pictorially and with explanatory text thereby providing information in a variety of formats for different audience comprehension levels. Watch this video of two students enthusiastically sharing their results at a science fair. They could even develop junior and senior level 'quizzes' about their work to further engage their listeners and readers.

On completion of scientific investigations around a theme such as 'Global Issues', class knowledge and understandings could be applied if students developed a webquest around the issue. Support for the use of webquests as a strategy to demonstrate learning is found on the Australian Government Quality Teaching Project website. Alternatively you may choose to support students to construct a PowerPoint presentation to communicate the key aspects of their investigation. This serves a dual purpose since PowerPoint slides may be used in a computer presentation and also individually printed for displaying on a poster (Prezi is an alternative to PowerPoint that you might like to try). An extension of this is the digital portfolio that contains a tutorial to support the development of non-linear power point presentations.

Videos of student investigations or science fairs can be taken and the following site provides support to teaching students to edit the videos for more effective communication. (non DET link)

Demonstrate your learning

Explicitly teach a lesson about the metalanguage of science in which terms are represented for a variety of audiences.

View a selection of multimedia resources such as the ABC – Bernie's Basics. The same information is represented as a video (Fundamentals 'Hotter than Hot' from Catalyst on 18/02/2010 and in text form 'You're hot or you're not'). Compare the ways of representing the information with your class.

Conduct peer evaluation of students' presentations so as to help establish criteria that distinguish attempts to address different audiences.

Evaluating and Assessing Level 1

Evaluating and Assessing an Investigation

The domain 'Evaluating and Assessing' contains many components. Introductory activities (formative assessment) recognise student prior learning and skill development, so that the level of support offered to students can be more effectively managed. Student groups could be provided with a poor example of a 'fair test' investigation and asked to identify areas for improvement to establish student prior understandings. Throughout any investigation students should be encouraged to keep learning journals where they record their reflection and evaluation. Another component of this domain occurs when teachers make a summative assessment of the learning outcomes and achievements of students in their scientific investigation. Clear achievement criteria need to be communicated to students so that they understand exactly what they have to do to meet learning targets. The use of holistic rubrics can facilitate assessment of learning. Finally teachers should reflect and evaluate the processes they have undertaken themselves as they have facilitated student-driven scientific investigations.

What is evaluation?

Evaluation is the process of using data and evidence to make judgements about the effectiveness of teaching programs, policies and procedures. From the teachers' viewpoint, evaluation follows reflection on the learning activities and processes as well as the responses of students.

Watch a beginning teacher's evaluation of his *MyScience* experience.

Watch an experienced teacher discuss the experience of *MyScience* the second time around.

Student reflection

In addition to teacher evaluation, students are encouraged to reflect on their learning processes and evaluate. Research evidence is that students are generally honest and reliable when self-assessing but they must have a clear picture of the targets that their learning is intended to obtain (Black P. and Wiliams D. (1998), 'Inside the Black Box – Raising Standards Through Classroom Assessment'). Students need to be trained in self-assessment. They need to understand the main purposes of their learning and what they must do to be successful. Teachers need to learn to manage discussions that are designed to elicit student prior understandings so as to deal with unexpected responses from students in such a way as to NOT try to manoeuvre conversations to get predictable answers. Research suggests that students learn to play the game of guessing the answer that the teacher requires rather than thinking through situations aloud. Evidence suggests that increasing wait time or allowing small group discussions before students respond is essential to supporting learning. More information about student reflection is included in the level 2 learning pathway. Students could complete this drag and drop activity supporting reflection and evaluation of their investigative processes.

Watch a group of students recount their *MyScience* investigation comparing the memory of boys with that of girls. They outline their method but also reflect on areas for improvement.

We distinguish reflection from evaluation in that evaluation is the decisive or judgemental phase that follows from reflection.

A useful tool to support student reflection is the use of a learning journal (also called notebooking by some workers). Students use learning journals as individualised logs of their learning. They formulate and record questions, ideas or inspirations, make predictions, record data, procedures, results, conclusions or construct concept maps or otherwise show how they are making connections in their learning. They can use computers or pen and paper. Features such as Venn diagrams, box and T charts, flow charts, concept maps and tables are part of a learning journal. While they are useful for the final presentation on an investigation they are a valuable tool for teacher evaluation.

What is assessment?

The New South Wales Board of Studies in its Science and Technology Syllabus released in 1991 gave the following definition:

> *'Assessment is the process of gathering evidence of and making judgements about students' needs, strengths, abilities and achievements.'* (Science and Technology syllabus page 36)

Assessment has been classified as summative, diagnostic or formative. Summative assessment is carried out at the end of a learning activity or at a specific time and designed to determine student achievement. It is the basis of testing for comparison of educational standards nationally and internationally. Summative assessment has been more recently termed 'Assessment of learning'. Diagnostic assessment is usually conducted before a learning activity and is regarded as fairly formal so that major decisions about the structure of the learning may flow from the results. Formative assessment is regarded as less formal and on-going directed at ascertaining the progress, strengths and weaknesses of individual students and the effectiveness of instruction. Formative and diagnostic assessment, together have been more recently termed 'assessment for learning'.

Since 1991, Australia has participated in TIMSS (Trends in International Mathematics and Science Study — started in 1995) and PISA (Program for International Student Assessment — started in 2000) that make assessment and comparison, internationally, of student achievement of scientific literacy. To some extent, it appears that assessment has increased in importance and is a driving force in the development of national curricula. The Ministerial Council on Education, Employment, Training and Youth Affairs has overseen the National Assessment Program and is responsible for the 'National Assessment Program — Science Literacy 2006 School 'Release Materials'. The first national assessment program in science was conducted in 2003 in primary schools and was followed by a second test in 2006. Both tests sampled year 6 students and the second test included an objective assessment as well as a practical test. Tests are again being conducted in 2010. The preceding link contains test items, marking guides and student standard and performance profile. A Progress Map on Science Literacy is a quick reference in which strands A and B of the three strands of science literacy clearly relate to students' ability to recognise investigable questions, identify evidence needed for a scientific investigation, draw or evaluate conclusions and communicate valid conclusions. Strand C relates to knowledge and understanding. The Appendix 1 of this article describes six levels of achievement across three strands and relates these to the SOLO (Structure of Observed Learning Outcomes) taxonomy.

Not all assessment is summative or test-based. When students are investigating scientifically, structured observations will contribute to evidence of student achievement. Student reflection though a learning journal is a considerable support to assist teacher judgements about needs, strengths, abilities and achievements. For summative assessment, it is essential that teachers establish clearly to students the criteria for successful achievement when investigating. The Progress Map on Science Literacy (Appendix 1) clearly defines six levels of development over three strands. Alternatively, descriptors such as those that occur in the levels of the Young Scientist rubric may be adequate for teachers, but do contain some subjective comparisons. Judges of this competition undergo training in the use of the rubric to help them establish a clear understanding of the standards. Students will need to have criteria explicitly for their task outlined in a simple format.

Demonstrate your learning

Construct a table that identifies your efforts to promote student reflection and evaluation throughout your science investigation.

Identify three areas where you would change your teaching to improve learning while investigating scientifically.

Distinguish between assessment for learning and assessment of learning giving examples from your teaching of a science investigation.

Do the quick quiz to check your understanding of the Young Scientist Rubric.

Evaluating and Assessing Level 2

Reflection, self and peer assessment

Watch a student who has reflected on her *MyScience* experience give advice to other students who might be starting a *MyScience* investigation.

An excellent web site on Reflective Thinking provides extensive information including the characteristics of environments and activities that promote reflective thinking and a link to recommendations to promote reflective thinking. It includes students reflecting on what they already know, need to know and the process to achieve the relevant learning. It also includes the reflection on the learning process. Students could complete this drag and drop activity supporting reflection and evaluation of their investigative processes.

Assessment Criteria and Rubrics

Assessing students is often a matter of placing them along a continuum of learning. This can help in both assessment for learning and assessment of learning. *MyScience* web site has a resource that describes the continuum of learning that occur across the aspects of scientifically investigating of:

- raising questions
- predicting
- fair testing
- measuring
- developing tables
- constructing and using graphs and charts
- explaining results
- evaluating investigations.

Heinemann published a book 'Seamless Assessment in Science – A Guide for Elementary and Middle School Teachers' by Sandra K. Abell and Mark J. Volkmann in 2006. Chapter 3 of this book, including vignettes, is available online around the theme of life sciences and the 5 E's approach to science instruction. While there is no example of assessment of a scientific investigation, there are a range of assessment strategies for a range of levels and scientific concepts.

The Assessment Resources Centre (ARC) of the NSW Board of Studies provides a detailed grade commentary on work samples in an activity based on 'Investigating Scientifically' for stage 2 students. Work samples with explanations are provided on this web site and provide insights into developing 'consistent teacher judgement' when using the A-E grading system used in NSW schools. Six criteria for assessing learning are listed. This site also links to an activity to compare the strengths of various magnets for the same stage level. Links to a task in which stage 3 students investigate ways to construct a working simple electric circuit are also displayed.

Demonstrate your learning

Benchmarking: Use the Young Scientist Years 3-6 Rubric or the Progress Map on Science Literacy to assess the level of achievement of the students in the video clip on removing stains from clothing.

Use this quick quiz to check your knowledge of the Young Scientist Rubric.

Watch students reporting on their investigation about the effectiveness of a sport drink. Record the feedback that you would give to these students that indicates an understanding of the learning that they have demonstrated about scientific investigations and areas for them to develop further.

The Board of Studies has a site ARC (Assessment Resources centre) that contains work samples. This link is to the grade commentary for a work sample that relates to an investigation into ways of filtering muddy water. Use the five stated criteria for this activity to develop a holistic rubric for marking showing five levels of achievement.

Integrating ICT level 1

ICT can be integrated throughout the processes of the scientific investigation. It is most likely to be used when performing background research, planning through mind mapping, conducting online communication between students, mentors and teachers and the final processing and publishing of the investigation. While many simulations of investigations can be found online, they are not a satisfactory substitute for students actually conducting their own offline investigations.

Watch a beginning teacher talk about the benefits of using ICT when doing a *MyScience* investigation.

Getting started

A barrier to effective instruction in the use of ICT applications is lack of knowledge of the appropriate terminology. Familiarity with the terms arises with frequent use of ICT and an extensive glossary. Here is a link to a glossary of ICT terms. Another glossary with additional explanations is available through the parents and community link of TaLe.

Internet tutorials has a general article about the use of the internet for research. The following web site provides some advice on the use of the internet for research.

Communicating

Online communication between students, mentors and teachers can help a scientific investigation progress more efficiently. TaLe (under the link tools+) has advice about social media tools including email, online forums, blogs, wikis and podcasts. Learn more about wikis from this web site. NSW DET provides for its schools an Online Communication Guide which should be accessed.

One simple and direct way of facilitating communication between students and with their mentors is through email. A support tutorial for the use of email is found at AGQTP. Larger groups may prefer other social media tools. Cybersafety is essential and it is important to train students in cybersafety in sites such as Cybersmart. This site also provides support for the use of social media and networking if you follow links to schools and technology guides.

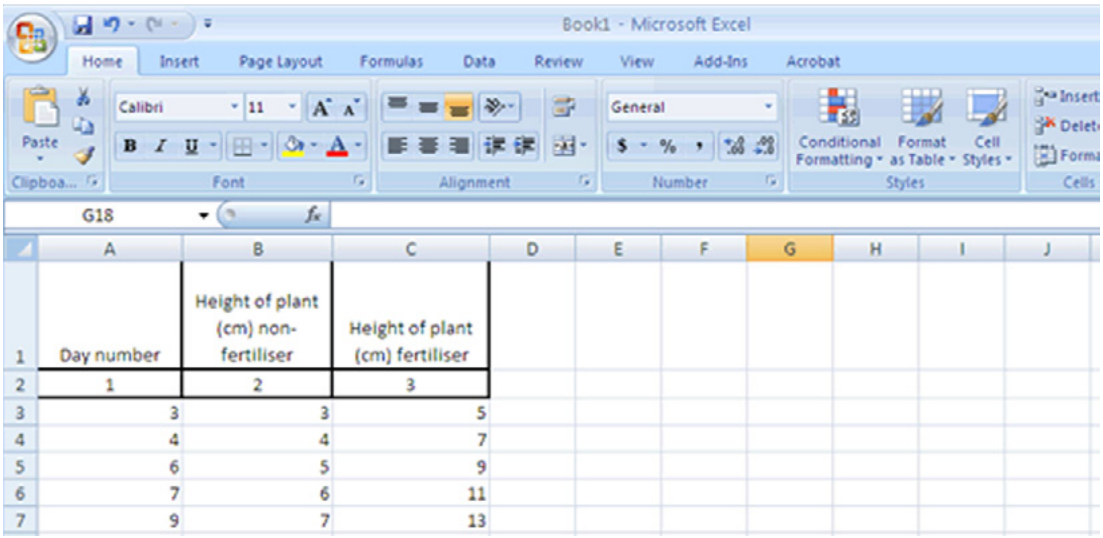
Processing and Publishing

Processing and publishing of scientific investigations generally involves the use of spreadsheets and word documents. TaLe also has information to support the use of Microsoft software including Excel, Word, PowerPoint and Publisher. You can access this information by following the 'Tools+' link. Support for Microsoft Frontpage is available on the Microsoft web site.

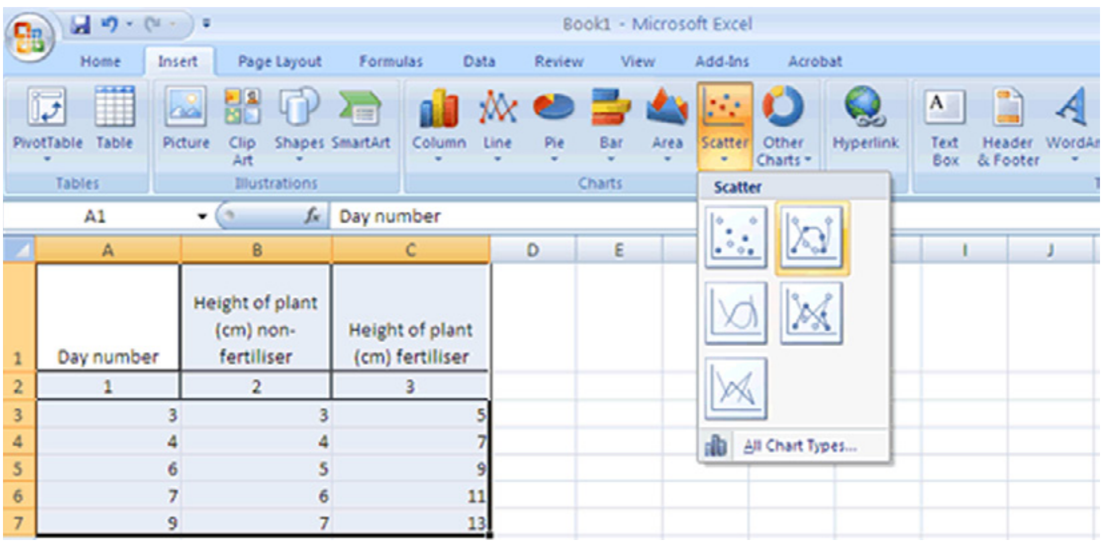
Using Excel for graphs

A commonly used application of ICT is the use of Excel software to create a table of results from an investigation and then use it to create a chart (graph). Here are a few tips for creating a line graph to represent continuous data.

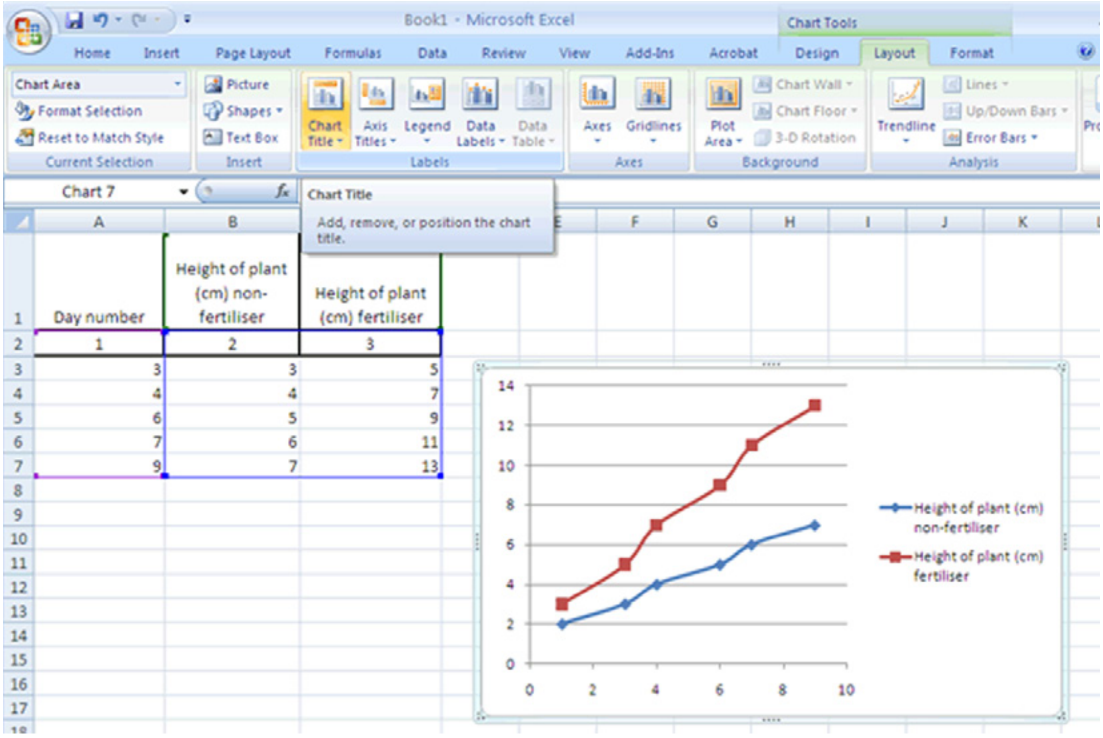
Enter the data so that the data for the x-axis is in the first column and the y-axis or dependent variable is in the second column. If two lines are required, for different treatments or experiments, then use an additional column. If, for example, students have measured the height of plants, some grown with fertiliser and some grown without and measured over three weeks, the first column would list the day number, the second column would be the height of the plants on each of the numbered days for the non-fertiliser and would have a heading ‘non-fertiliser’ and the third column would be the height of the plants for the numbered days grown with fertiliser and would have a heading ‘fertiliser’.



Highlight the columns and rows that you want for the chart and then click on ‘Insert’ and then, in the Charts group, click on the type of chart. If, in the above case, you want to include a legend with the graph for the fertiliser and non-fertiliser plants, make sure the headings are highlighted as well as the columns containing the data. Then for a line graph, SELECT a scatter (XY) plot. (There is a trap to avoid because line graph appears as an alternative, but it can only be used if the x-axis or horizontal scale is representing data on an even scale). In this data set the days when measurements have been taken are NOT evenly spaced. A range of types of scatter plots will appear. Click on the choice of the one you want (that is, do you want a line to connect the points or not, do you want the data points emphasised or just the line, do you want a straight or curved line to join the points?



Students can go to the 'layout' tab to select ways they can improve communication by adding a title, axes titles and so on.



Demonstrate your learning

Use software such as Free Mind, Inspiration or even Microsoft Word to create a simple mind map on a topic you are currently teaching in science.

Use ICT to create at least two types of graphs and then teach the steps to your class.

Reflect on your use of ICT to promote communication between students and mentors while investigating scientifically.

Integrating ICT level 2

Watch a beginning teacher talk about the use of ICT in *MyScience* investigations.

Expanding teaching strategies with ICT

Seamless use of ICT arises when there is a genuine benefit from the use of ICT in the context of the purpose of the learning. Essentially ICT supports small group work and differentiated learning that is a key component of the *MyScience* investigations. It might be worth visiting the level 1 pathway to review the use of ICT for communication between students, mentors and teachers when planning and conducting the *MyScience* investigations or for processing and publishing results. ICT also has application for student groups researching the background science to their investigations.

ICT can also be used in the early stages of planning a *MyScience* investigation by helping students to negotiate how to proceed with their investigation task and to expand their learning strategies. The CLAS web site has a tutorial that explains the benefits of, and steps involved in the use of the Intel Visual Ranking Tool. You could use this to promote discussion. Each student group and their mentor could eventually create their own list of potential investigations and then use this tool to establish a consensus.

When students and teachers have confidence and skills in the use of ICT, the final published product of a *MyScience* investigation can be a multimedia presentation that can more effectively cater for a wide range in audience. Generally, younger audiences require more interactive and visual communication. Students may need to be prepared to speak with parents and mentors using scientific terminology, but also need to be able to simplify some of the terms for their younger audience members. (See glossary or go to the Knowing and Thinking pathways.) Multimedia allows for flexibility in communication and so the different audiences are more easily addressed. Weeds Attack on TaLe is a multimedia resource that encourages students to produce a digital story to 'Spread the News' and even includes a digital story wizard. Adobe Presenter is one tool to assist creating high quality media presentations using PowerPoint as a starting point. Quizzes can be added and a branching pathway created depending on the responses of the participants. Adobe Connect Pro 7 provides the potential for online collaboration that could provide some alternatives to face-to-face meetings with mentors.

The Connected Classrooms Program and its Interactive Classrooms Project provide support for NSW DET teachers who are changing their teaching to seamlessly incorporate ICT. Learn what other classrooms are doing through the Connected Classrooms Project and its newsletters. One of the best ways to transform teaching methods is to make effective use of an interactive whiteboard (IWB). This link provides support for teacher learning to use the SMART Notebook to create resources for use on the interactive whiteboard. Non DET schools can access this link. An interactive whiteboard can be used for the initial brainstorming/mind mapping of a topic and the mind map can be saved. It can be re-visited in the final stages of the investigations when students are analysing the implications of their results. It is also useful for student presentations. Student groups have even used an interactive whiteboard in their investigation. One group investigated whether yawning was contagious and hence used the whiteboard to show clips of a person yawning and then assess the impact on the audience. An example of a simple activity for a class is to use the Smartboard to sequence the steps for constructing an Excel spreadsheet and then a chart. This example of a crossword puzzle on terms in scientific investigations, because it is generated using Smart Notebook, allows students to collaborate as they try to solve the puzzle.

Moodle is a tool for creating online dynamic web sites. Learn about Moodle here. NSW DET schools can investigate how Moodle has been used to change the instruction at a school.

If you want to learn more about the results of UK based BECTA research into the use of ICT and classroom organisation follow the link.

Demonstrate your learning

Choose either the Intel Visual Ranking Tool, one of the multimedia software support systems or Smart Notebook to change one aspect of your teaching or student demonstration of their learning to incorporate ICT to more efficiently achieve your educational goals.