Working scientifically

Introduction

‘Working scientifically’ involves the processes of science, including understanding the sorts of questions that are the province of science; the design of experiments; reasoning and arguing with scientific evidence; and analysing and interpreting data.

Detailed discussion of working scientifically in primary schools can be found in Keith Skamp’s *Teaching primary science constructively* (Thomson Learning 2004). An example of the forms of knowledge associated with working scientifically can be found in the Victorian Curriculum and Standards Framework (CSF) for science, which can be found on the Victorian Curriculum and Assessment Authority website <http://www.vcaa.vic.edu.au/index.html>.

Key concepts of working scientifically

The activities in this topic are designed to explore the following key concepts:

- ‘Working scientifically’ involves particular forms of reasoning with evidence that is different in detail from reasoning in other areas.
- There is no one ‘scientific method’, but many ways in which scientists plan to establish ideas and generate evidence to explore and support these ideas.
- An oft-cited example of scientific method is the controlled experiment, where the relationship between an effect and a variable is explored, with other potentially confounding variables controlled (i.e. kept the same). An example would be the exploration of the effect of the length of a pendulum on its period of swing, keeping the weight and swing size the same but varying the length and timing of the swing. However, for many branches of science, this type of control is not possible. For instance, in studying ecological systems, in many cases theories must be established by looking at existing ecosystems with many variables. In geology and astronomy the idea of controlling and repeating observations is very different. What is common to all these areas, however, is the collection of evidence to support or argue against claims, and reasoning with evidence that attempts to isolate clear causes for phenomena.
- Working scientifically involves a number of ‘concepts of evidence’, including the purpose and techniques of focused observation, the recognition of a scientific question that can be investigated, the need for repeat measurements and skills in devising measurement processes, ways of recording data (these can vary considerably) and representing data for

analysis, different experimental designs and associated principles (e.g. understanding 'sample size' in making observations in the field), and reporting.

Students' alternative conceptions of working scientifically

Research into students' ideas about this topic has identified the following non-scientific conceptions:

- Students will not immediately see the task of an investigation as exploring ideas or looking for patterns, but will treat an investigation simply as 'establishing what is' without thought for considering alternative interpretations.
- Students have problems recognising what is an investigable question and will propose questions such as 'What is electricity?' as the basis for investigation. Their questions need to be worked with and clarified to become amenable to scientific investigation.
- Students will not understand many of the concepts relating to measurement—for instance, the reading of a scale, the recording of comparison measurements using consistent processes, the calibration of instruments, the need for repeat measurements and the concept of uncertainty in measurement. They need to be supported in making defensible measurements.
- Students can understand the need to control variables in simple situations (to make the test 'fair'), such as the need to use the same amount of each type of sugar when comparing the solubility of sugars. However, they have difficulty in cases of interacting variables (e.g. finding out the separate effects of weight and length on a pendulum swing, or the separate effect of light and moisture in determining where slaters prefer to live).
- Students will not understand the power of laying out data in tables and graphs, and the use of a table as a design organiser to help plan a series of measurements.
- Depending on their knowledge and experience, students may have trouble arguing clearly from evidence.

It has been amply demonstrated that, with appropriate support, even very young children are capable of distinguishing between observations and inferences, of asking investigable questions, planning experiments and arguing from evidence.

Consumer science

'Consumer science' refers to activities in the classroom whereby students use scientific processes to make judgments about consumer products. Although consumer science does not fall easily into any major curriculum topic categories, it is an important and fun vehicle for teaching students about some of the science processes such as fair testing, measuring and recording. It provides a vehicle for learning about the nature of scientific investigation.

It should be noted, however, that these investigations, because they mostly involve comparisons on the basis of criteria, do not illustrate the more difficult nature of working scientifically that deals with the exploration of conceptual ideas.

Skills and understandings of consumer science

The activities in this topic are designed to develop the following skills and understandings of this topic:

- how to formulate useful, investigable questions
- the importance of measuring accurately
- why it is necessary to ensure that all tests are fair and repeatable
- the purpose of planning and designing investigations
- how to design valid experiments with appropriate variable control
- how to design measurement procedures
- how to represent data for analysis and reporting.

Things to consider when completing activities

The activities in this topic give examples of some types of products suitable for early and middle years consumer science testing. In judging different products, the things that need to be considered (summarising the discussion above) are:

- what criteria are relevant for the evaluation
- what weighting should be given to the various criteria
- whether the test is fair
- whether the results are reproducible
- whether the method of comparison (scale, addition of scores, etc.) is appropriate.

Development of students' testing capabilities

The following descriptions of students' capabilities at different year levels, and the type of activity appropriate for each, are based on reports of Deakin University students teaching consumer science activities to groups of students in schools.

Prep/Year 1

It is most appropriate to structure tests and scaffold children's experimenting.

Criteria and procedures need to be decided by the teacher, using simple tests and comparisons, rather than measurements. Ensure there is a low demand for manipulation skills.

Examples of appropriate tests include comparing the sweetness of cereals, the amount of salt or oil in chips or the amount of bubble in detergents.

Year 2

Students can define criteria, but have little understanding of a fair test, e.g. so they may cheat to make sure their chosen sample ‘wins’.

Year 3

Students are beginning to appreciate the notion of a fair test. They can define criteria and conduct given tests with fairness and appreciate how differences in results can arise.

Year 4

Depending on the content area, students should now be able to design experiments and plan measurements with minimal input from the teacher.

Years 5 and above

The comparison of products by discussion of weighting of criteria is increasingly possible. Students are able to set out tables and deal with different orders on different criteria. They can hold a reasoned discussion on the factors affecting the performance of different products, and ways of exploring these further.

Activities

Exploring consumer science

Key ideas: Articulating and refining questions. Designing experiments and controlling variables. Developing measurement procedures. Constructing and interpreting data representations.

ACTIVITY: POTATO CHIPS

Teaching note: This activity can be used for all levels but will need to be adapted accordingly. Have the students work in groups. Each group should have a scoresheet and a recorder, a reporter, a timekeeper and someone to hand out each item. Make sure all the students take it in turns to taste the items. You might want to collect the information and collate it on the board. Some discussion of the problems with testing, especially the problems associated in keeping things ‘fair’, should be encouraged.

You will need:

- **a variety of brands of potato chips**
- **brown paper squares**
- **brown paper bags**
- **rolling pins**
- **breadboards**
- **jars of water.**

a) Test for salt content

Taste directly—have ONE student taste each brand of chip to determine and give their opinion of which is the saltiest. It might be a good idea to blindfold the student so they do not see the brand they are tasting and select their favourite (or least favourite, accordingly).

Dissolve in water and taste (what will you control?)—crush a chip of each brand (making sure you keep the samples the same size) and put the crumbs of each chip into separate containers with about 40 mL of water. Add a pinch of salt to another 40 mL of water. Have a clean glass of water on hand. Alternatively taste the salted water and each chip water, taking a sip of fresh water in between tastes. Which is saltier?

b) Test for oil content by rubbing between sheets of brown paper
Place a chip between two sheets of brown paper on the breadboard, and then crush it by rolling over it with the rolling pin. How much oil appears on the brown paper? Measure the spot using a ruler.

Alternatively, place a chip on top of a pile of brown paper pieces. Roll over it using the rolling pin. How many thicknesses of paper did the oil penetrate? Hold the oil patch over some print or up to the light. How translucent is the patch?

Repeat the experiment for the other brands of chips.

c) Taste test
Place a sample of each brand of chip into a paper bag. Have one student act as the taste-tester (only one student at a time should test the chips!). Get the student to taste each brand of chip from the unmarked bags. It might be a good idea to get them to have a sip of clean water between each taste. What could they test for (e.g. crunch, flavour, texture)?

d) Testing the packaging
Examine the packaging that the chips come in. How is the manufacturer trying to sell the chips? What colours are used in the packaging? What is the salt or fat content according to the nutrition label? Is there a trinket included in the pack? Is this important to the group? How easy are the bags to open? Rate what the students think of each and keep score. Which brand of chips is considered to be best according to its packaging? Why?

Rank the criteria in order of importance. Which chips would you recommend?

ACTIVITY: CEREAL

Teaching note: This activity is similar to the chip experiment above and so the same guidance should be offered. The experiments outlined above for potato chips can be carried out for cereals, although you should test for sugar content instead of salt!

You will need:

- **a variety of cereal packages.**

Look at the packet nutrition guide. Compare cereals for sugar, fat, carbohydrate content.

ACTIVITY: TESTING BALLS

Teaching note: This activity is suitable for all levels depending on the comparisons made.

You will need:

- **a range of types of balls, e.g. tennis, squash, ping-pong, golf, rubber, plastic**
- **a range of different surfaces, e.g. carpet, concrete, grass**
- **a metre rule.**

a) The bounciest ball
Ask the students to form a group and make up a table to record their results. Each group should have at least a recorder, a reporter and an experimenter. Choose a surface and drop each ball from a height of one metre. Which ball bounces the highest? Which ball bounces the most? Record the results.

b) Do surfaces make a difference?
Try all the same experiments on different surfaces. Does the type of surface make a difference to the results? Why?

c) A case of different criteria for different purposes
Discuss which ball would be best for what purpose. Some ideas for comparing the balls are investigating: which ball rolls straightest along a surface, for use in bowling; which ball is most suitable for a throwing-and-catching game.

ACTIVITY: ERASERS

Teaching note: This activity is suitable for middle years students. The challenge is to compare different brands and types of eraser.

The sorts of criteria that might be appropriate for comparing erasers include efficiency, cleanness of finish, how long-lasting, effect on paper, ease of handling and cost. For each of these a measurement method and a set of criteria for coming up with a score would need to be devised. We have found a score out of five is adequate—it is hard to judge on a ten-point scale. An alternative is to rank the erasers for each criterion. A table can be set up to enter the scores, which can then be averaged, or even given a weighted average.

You will need:

- **a grey lead pencil**
- **five or six different types of erasers**
- **paper.**

For testing the effectiveness of the eraser, the idea is to rule five or six pencil lines depending upon how many erasers you are testing (remember: the lines must all be the same length).

As an example, when you rule a pencil line to rub out to test which eraser is most efficient, you will need to control:

- **the type of paper**
- **the length, width and density of the line**
- **the strength of rubbing.**

Will you compare after a given number of strokes, or count the strokes needed to erase completely? What other criteria apart from erasing efficiency might be appropriate? How could you arrange for the whole class to come up with displays of comparable results?

ACTIVITY: STICKY TAPE

Teaching note: This activity is suitable for students in the middle years. Students should work in small groups or pairs. Ask students to design a series of tests to determine the strength of the various tapes.

You will need:

- **a variety of brands and types of tape**
- **a mirror or smooth surface.**

Which is the strongest? (How much weight is needed to peel a piece of tape off a mirror? Arrange a suitable set of tests.)

Which re-sticks the best? (How many unpeelings before no stickiness is apparent?)

Which sticks best to different types of surfaces (rough, wet, cloth)?

Are there other relevant criteria?

ACTIVITY: PAPER TOWELS

Teaching note: This activity is suitable for students in the middle years.

You will need:

- **a variety of paper towels**
- **a beaker of water**
- **an eyedropper**
- **a ruler**
- **weights (e.g. brass 50 g weights, or metal bolts of the same size)**
- **a measuring cylinder.**

a) Which absorbs the most water?
Using the eye-dropper, put a drop of water into the middle of the paper and see how far it spreads. Dip the towel in water in a beaker and see how much is absorbed. Devise a standard spill and see which towel cleans it with the fewest sheets.

b) Which is the strongest?
Support the towel at the edges and measure how many weights it can hold before breaking. Is dry or wet strength the most relevant?

ACTIVITY: GLUES

Teaching note: This activity is suitable for students in Year 3 and above.

You will need:

- **a variety of paper glues**
- **paper strips**
- **icy-pole sticks**
- **weights (e.g. brass 50 g weights, or metal bolts of the same size)**
- **a clock.**

What do you expect from a good paper glue? Compare the glues to check which is best.

General-purpose glue: glue two icy-pole sticks together and check the weight needed to break the bond.

Paper glue: glue paper strips together and time how long it takes to dry. Alternatively, rate the stickiness of the glue. Does it mark the paper?

ACTIVITY: DETERGENT

Teaching note: This activity is suitable for students in upper primary years.

You will need:

- **a variety of detergents**
- **microscope slides**
- **Vegemite**
- **butter or oil**
- **a 5c piece**
- **beakers.**

Make up solutions of the different detergents and water, of comparable strength.

a) Compare the foaming actions.

b) Put a drop of oil on a microscope slide. Devise a method for comparing how easily the detergents remove it. Repeat the same experiment using Vegemite on a microscope slide.

Compare how many drops can fit on a 5c piece (the better the detergent, the fewer drops).

ACTIVITY: MUGS AND CUPS

Teaching note: This activity is suitable for all levels but the more complex tests are suitable for students in upper primary years. Be careful using hot water.

You will need:

- **a variety of mugs or cups**
- **hot or iced water**
- **thermometers.**

Compare a range of mugs or cups according to different features. This might include stability, feel, ease of handling and aesthetics.

Design a series of experiments to investigate their effectiveness in keeping tea or coffee hot, or keeping cold drinks cold.

ACTIVITY: WATER RESISTANCE OF CLOTH

Teaching note: This activity is suitable for students in Years 3 and 4.

You will need:

- **a variety of types of fabric**
- **a beaker of water**
- **an eye-dropper**
- **a ruler.**

Using five different types of fabric of approximately equal thickness, design, carry out and report on an investigation of the materials provided. Which fabrics are best for keeping dry?

There can be some confusion between the ideas of water absorption and water resistance. One way of measuring resistance is to spread the cloth over a glass and drop water on it, timing how long it takes for the water to run through. Some cloth will absorb the water rather than allow it to pass through. How would you judge this?

Oobleck: exploring how scientists work

This activity, using an intriguing substance (Oobleck, made of cornflour and water) that has properties unlike either normal liquids or solids, explores the way scientists share ideas.

ACTIVITY: SETTING UP

You will need:

- **a plastic bowl**
- **a spoon**
- **a measuring cup**
- **ingredient 'X' (cornflour: i.e. maize flour, not wheat flour)**
- **water**
- **green food colouring.**

Pour about a cup of ingredient 'X' into the bowl. Add about half a cup of tap water along with a few drops of green food colouring. Stir in the ingredients until a smooth paste is formed.

When the paste is just the right consistency, it is very difficult to stir quickly but still quite easy to stir slowly. More 'X' or water may be added to achieve this consistency.

ACTIVITY: SOLID OR LIQUID?

Imagine a space probe has just returned from a planet in another star system. The planet is covered with large, green oceans, and a sample of the ocean material was collected by the space probe. Imagine you are a group of space scientists gathering to investigate the properties of the ocean sample from outer space. Can the next space probe safely land on this ocean?

Oobleck is a strange substance. It is your job, as a group of scientists, to construct a list of properties of Oobleck. When you list the properties, make sure the language you use is clear, so anyone can understand what you mean. (Don't say 'It's scummy', say 'It feels wet to touch, but small drops dry when … '.)

Under what circumstances does Oobleck act like a solid, or a liquid? Which observations help you to work this out? Can you provide evidence for your assertion? Why do you think Oobleck behaves like this? Come up with a hypothesis.

ACTIVITY: SCIENTIFIC CONVENTIONS

Professional scientists in most fields come from all over the world to attend meetings called 'scientific conventions'. During a convention, scientists listen to each other's experimental results and critically discuss them. The goal is not to prove each other right or wrong, but to find the truth and to state it as clearly and completely as possible.

The class is about to hold a scientific convention on Oobleck. The properties listed on the board are the scientific results to be discussed, according to the following rules:

- **Only one property of Oobleck will be discussed at a time. First, one lab team explains or demonstrates the experiments that led to the property they focused on.**
- **Students who wish to agree or disagree with the property being discussed are invited to raise their hands to explain why.**
- **The class will find ways to change the wording of a property so everyone can agree on it.**
- **After fully discussing a property, the class will vote on whether or not it is really a property of Oobleck. If three-quarters of the class votes for a property, that property is called a 'law of Oobleck'. For example, 'Water changes from liquid to solid below 0° C' could be called a 'law of water' as most scientists would agree with this.**

Aim to come up with at least two laws of Oobleck on the board.