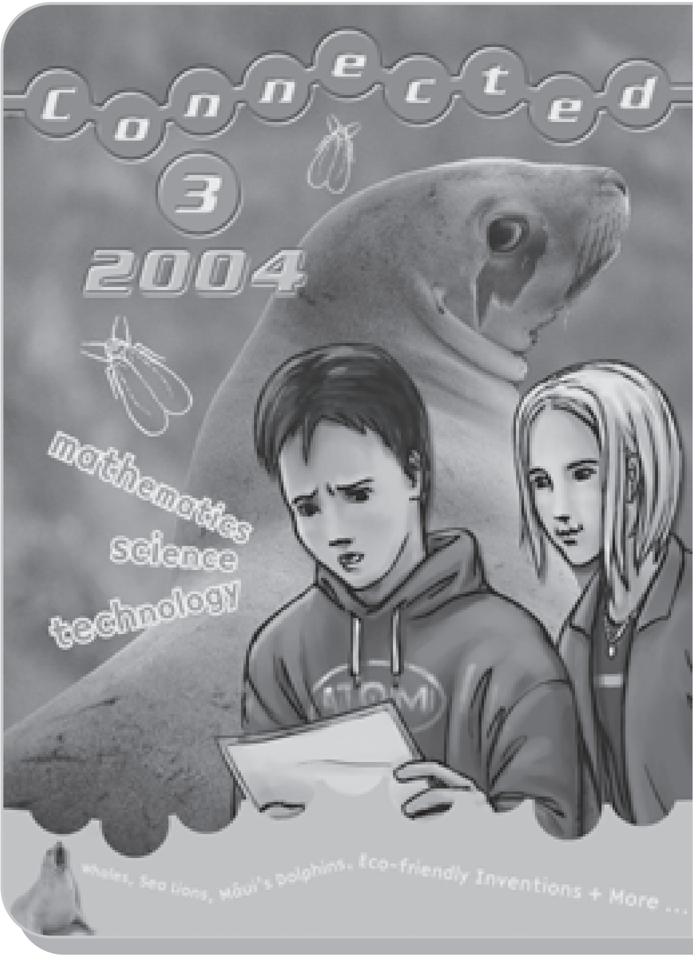
MINISTRY OF EDUCATION

Te Tāhuhu o te Mātauranga



Notes for Teachers

Connected 3 2004

Contents and Curriculum Links

Introduction

Connected is a series designed to show mathematics, science, and technology in the context of students' everyday lives. The stories and articles provide starting points for further investigations by individuals, groups, or a whole class. The activities in Connected 3 make science, mathematics, and technology fun for students working at levels 2 to 4 of the New Zealand Curriculum.

General Themes in *Connected 3 2004*

The overarching theme in *Connected 3 2004* is the conservation of endangered New Zealand species such as the southern right whale and Māui's dolphin, formerly known as the North Island Hector's dolphin ("Close Encounters" and "A Tragedy at Sea"). Much of this conservation can be achieved by keeping track of population numbers and by monitoring and improving the habitats of endangered species ("Down for the Count" and "Wonderful Water"). Another focus of many conservation initiatives is the control of pest species in environmentally friendly ways ("Eco-friendly Inventions").

1. Perspectives on the Nature of Science

In "Close Encounters", marine mammal expert Ramari Stewart describes how she blends Western scientific and traditional Māori perspectives and practices as she studies Campbell Island's sea lions and southern right whales. The teachers' notes that accompany "Close Encounters" and "A Tragedy at Sea" (which profiles research into Māui's dolphin) include discussion points and activities that explore traditional and contemporary world views and ways of building and communicating scientific knowledge.

2. Biostatistics

"Down for the Count" illustrates how important it is to monitor the numbers of endangered species such as Māui's dolphin. However, a seemingly simple procedure like counting is often complicated by the fact that many animals are very mobile and sometimes out of sight. Plants are sedentary, but often so numerous as to make exact counting difficult. The notes that accompany "Down for the Count" explore how biologists often gather accurate population statistics through various sampling techniques rather than attempting a full count. The notes include discussion points and practical exercises, some of which link with "Wonderful Water", a fictional piece about testing the water quality and ecology of local streams.

3. Environmentally-friendly Pest Control

"Eco-friendly Inventions" describes the development of sticky, yellow pest strips to trap whitefly and the invention of a machine that kills weeds by blasting them with very hot steam. Both inventions are designed to reduce our reliance on toxic chemicals to control pests. The teachers' notes take a technology/environmental education approach that centres on direct action by students in initiatives such as adopting a local stream or developing and implementing a programme to reduce toxic pesticide use in the school grounds.

Acknowledgments

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“Close Encounters” and “A Tragedy at Sea”

Possible Achievement Objectives

Science

Nature of Science

- Achievement Aim 1: Critically evaluate ideas and processes related to science and become aware that scientific understanding is developed by people, whose ideas change over time.
- Achievement Aim 3: Gain an understanding of personal, community, and global implications of the application of science and technology.

Living World

- 3.1: Distinguish between living things within broad groups on the basis of differences established by investigating external characteristics.
- 4.1: Investigate and classify closely related living things on the basis of easily observable features.
- 3.2: Investigate special features of common animals and plants and describe how these help them to stay alive.
- 4.2: Investigate and describe special features of animals or plants which help survival into the next generation.
- 3.3: Research and describe how some species have become extinct or are endangered.
- 4.3: Investigate and describe patterns in the variability of a visible physical feature found within a species.
- 3.4: Explain, using information from personal observation and library research, where and how a range of familiar New Zealand plants and animals live.

Developing the Ideas

It is suggested that the students read “Close Encounters” and “A Tragedy at Sea” together as both articles show how scientists look at the world through different lenses. For example, Ramari Stewart compares Western scientific and traditional Māori world views and combines aspects of them that are positive and helpful in each situation or setting. She offers a glimpse of the benefits that could be gained as we become a more bicultural society. Like many scientists, Kirsty Russell is also an environmentalist. She combines her scientific practice and philosophies with an environmentalist world view that blends the science of ecology with spiritual notions of guardianship and responsibility. These latter philosophies accord with the Māori concept of kaitiakitanga, discussed later in these notes.

This issue of Connected could help students to begin (or continue) a conversation about how culture shapes the way we build knowledge and think about our world. A very useful scene-setting activity would be to have the class watch the movie *Whale Rider*. Many of the ideas conveyed in *Whale Rider* match with Ramari’s philosophies.

The Specific Learning Intentions

The **ideas** to be explored are linked to the aims of the integrating strand Making Sense of the Nature of Science and Its Relationship to Technology. The suggested **activities** link this "Nature of Science" strand with Developing Scientific Skills and Attitudes and the contextual strand Making Sense of the Living World.

The students will be able to:

- make careful and purposeful observations;
- identify the evidence that is used for making some knowledge claims.

The Key Ideas

- There are different ways of looking at the world (world views) and each person's world view has a strong cultural component.
- Each person's world view offers important ideas for others to think about.

Contrasting Ideas in Māori and Western Scientific World Views

The following notes present discussion topics that address seven important differences between a Western scientific and a Māori world view. The ideas may challenge some students' thinking. For example, students who are not familiar with Māori culture may say that certain aspects of it are "wrong". Another challenge may be that many students will not recognise science ideas as coming from a specific culture at all. (If this comes up in discussion, you could use the analogy of the surfers in "A Tragedy at Sea" who had no idea that they were swimming with endangered dolphins because the Māui's dolphin was the only species they saw regularly. We often think of what is familiar to us as just "the way things are".) Note that the following ideas are general. There will always be personal and regional exceptions and differences in emphasis and detail.

1. Wholes and Parts

In Māori culture, the world is seen as a whole. However, Western scientists may study individual aspects of the world separately. Towards the end of the twentieth century, and increasingly nowadays, scientists are acknowledging the importance of studying whole systems. This is bringing their world view closer to that of Māori. In "Close Encounters", this difference is highlighted when Ramari calls herself a naturalist not a biologist.

2. What Can Be "Living"?

Scientists divide the world into "living" and "non-living" things, defined by an agreed set of criteria. (These criteria are explained in the Ministry of Education's *Making Better Sense of the Living World* [Learning Media, 2001], pages 22 to 24.) Māori make no such distinction because they believe that all things are interconnected through their whakapapa or genealogy. In this view, everything in the world is infused with a life force. This includes rocks, water, and other objects and materials on the Earth's surface that scientists would call non-living.

In "Close Encounters", this difference is highlighted when Ramari refers to a headland as Tupuna, the ancestor. She thinks of this landform as a guardian. Many Māori karanga the land before entering areas such as native bush. In such a karanga, the caller greets the spirits of the land, invokes their protection, and asks permission to enter the area and use the resources it has to offer.

Activity

For an activity on sorting living from non-living things according to a mainstream scientific outlook, see page 26 of *Making Better Sense of the Living World*. After the students have carried out the activity, ask them some questions that might challenge their assumptions. *Would people from other cultures necessarily have the same views about the criteria for distinguishing living and non-living things*? *Would people from other cultures necessarily think in terms of living and non-living categories at all? Are there grey areas even within the Western outlook? For example, is a recently cut flower living or non-living?*

3. Spirituality

A related idea is that it is important to acknowledge and respect the spiritual components of the world. In the traditional Māori world view, spiritual forces are not detached from observable physical phenomena. Several centuries ago, scientists agreed to build their ideas by using nothing other than things they could observe and measure. Since spiritual things cannot be observed or measured, they cannot exist in mainstream science theories. This does not mean that spirituality cannot be an important component of scientists' lives. They simply keep their spirituality separate from their science knowledge building.

4. Rules for Building Knowledge

The idea that here could be a "set of rules" for building knowledge may be novel for many students. One of the distinguishing features of Western science is that the rules have always been discussed and written down on paper, making them open to challenge and debate. These rules are not fixed. Rather, they are developed by consensus among expert scientists as their knowledge field evolves. Such rules include what is to be measured, how it is to be measured, and what can count as evidence.

5. Ways of Grouping Living Things

What scientists call the "classification of species" Māori call "whakapapa". Whakapapa links are based on sacred legends handed down from the ancestors and are not open for revision. The guardians of this knowledge memorised whakapapa. Special chants helped them to remember the numerous details. (There is a scene in *Whale Rider* that shows potential future leaders learning such a chant.)

Scientific classification of the living world is based on the theory of evolution, and genetics has given scientists a new tool for observing and measuring interspecies relationships. (Earlier classification was based on how similar species looked.) For example, chimpanzees are now regarded as humans' closest relatives because they have the genetic make-up most similar to ours. Genetic analysis has led to the revision of some species definitions. This idea is illustrated in "A Tragedy at Sea". What was once considered one species (Hector's dolphin) is now divided into two species because of the extent of genetic difference between them. Thus, like all science theories, currently accepted classifications are open to challenge and revision.

Activities

Activities that explore the classification of animals are described in the Ministry of Education's *Is This an Animal?* (Book 39 in the Building Science Concepts series, Learning Media, 2003). For activities that explore the classification of whales and dolphins, refer to the Ministry of Education's *Mammals* (Book 55 in the Building Science Concepts series, Learning Media, 2004). This booklet outlines the main differences between baleen whales, such as the southern right whale, and toothed whales, such as the killer whale.

6. Views of Nature

Although we tend to talk about nature as if we all mean the same thing, there are different ways of thinking about it. The following is a broad overview of two very different ways of regarding the natural world.

One world view is that the world is here to support humans and their activities – although people may be expected to act as guardians of natural resources. In this view, humans stand apart from nature and are somehow different from "animals" – although, in terms of scientific classification, we are of course animals. This view has tended to prevail in Western thought, but newer theories of ecology are moving towards the world view described next.

A different world view sees humans as having no right to take from nature more than they need to survive. In this view, humans are just one small part of the natural world and are immersed within nature. We have a duty of care to other living things, which have just as much right to survive as we do. This is more akin to the traditional Māori world view expressed through the concept of kaitiakitanga and to the philosophy of sustainable development.

In many cultures, things in the natural world, such as whales and the land itself, were seen to protect humans (although often those cultures did over-exploit natural resources). *How and why have guardianship roles been reversed so that humans now need to protect nature?*

Activity

"Close Encounters" is a "think-aloud" piece in which Ramari describes significant experiences and explains why she sees the world in the ways that she does. You could encourage the students to write think-aloud pieces in which they reflect on and discuss their own and each other's views of nature. You could give them starters:

When I see/hear/smell/feel …, I think about what/how/why …

7. Observation Skills

Observation was important to Māori, just as it is to scientists. In "Close Encounters", Māori ways of intuitively observing are described as "ancient skills". The students could talk about the sorts of things you might need to know or imagine in order to "think like" the species you are hunting. (Not all students will accept the notion that animals think at all. This could be an interesting prior discussion point because it will probe aspects of the students' own world views.)

Intuition can be important for scientists too. However, in line with their rules for knowledge building, they must look for evidence that they can describe, draw, measure, count, photograph, and pass on by way of reports and articles on paper and, in recent times, the Internet.

Activities

The students could carry out simple observation activities to explore the difference between what you can see, remember, and talk about and what you can remember and convey if you have paper available.

What You Need

- A potato for each student or group
- Photographs of two closely related living things for each student or group

What You Do

Find Your Spud

- Give each student a potato and some time to observe it very carefully.
- Gather up the potatoes and mix them together.
- Ask each student to find their potato again and explain how they know they have the correct one. (This activity can be carried out in groups of 6 to 10 if you have a big class.)

What Am I?

- Give each student pictures of two related and familiar organisms, such as two types of dog or two types of flower.
- Have the students carefully observe the features of their dog or flower and describe it to the other group members without naming it or showing them the picture.
  How easy is it to convey clear observations using just words?
  What are the most helpful distinguishing features?
- Now let the students draw their dog or flower and see if that makes the communication of ideas any easier. You could discuss how much easier it is to learn about the different types of dolphins and whales described in "Close Encounters" and "A Tragedy at Sea" when there are also pictures to look at.

What You Look For

- Can the students describe the sorts of features that helped them to identify particular organisms and species?
- Can they link these observation activities with Ramari's and Kirsty's field observations? (You could ask further focus questions about this. *What helps naturalists and/or scientists to identify individual whales or dolphins? What helps them to classify separate species? Why would they need to do these things?*)

Other Ways of Thinking about Evidence

The two articles could also be used to help build the students' skills of argumentation – the assertion of evidence-based knowledge claims. On the basis of their general knowledge and the content of the articles, small groups of students could answer the following types of question.
What is the evidence that dolphins are intelligent animals?
What is the evidence that Māui's dolphins are endangered?
Are humans to blame for the decline in the numbers of Māui's dolphins? What is the evidence?
Do sea lions eat squid? What is the evidence?
Are sea lions afraid of humans? What is the evidence? (In this case, you could talk about whether evidence in one specific case is sufficient to make a more general case. If not, what other evidence would you need to gather before you could be confident of your claim?)

A more challenging approach would be for you to pose a question and ask the students to explore the sorts of evidence that they would need in order to answer it.

Further Activities

Living World Research and Discussion

The previous discussion points and activities centre on the integrating strands, but there is also plenty of scope for the students to carry out activities that address the Living World achievement objectives at levels 3 and 4. For example, they could carry out additional research into the biology of marine mammals or other organisms as part of the Nature of Science discussions and activities. This sort of research could also be part of an environmental education activity in which the students develop and carry out an action plan to promote public awareness of Māui's dolphin conservation initiatives or those to protect another local plant or animal. Sample specific learning intentions follow.

The students will be able to:

- distinguish between sea mammals and other large sea animals such as sharks and say how and why scientists group animals as they do (**LW 3.1**);
- identify different types of sea mammal and describe some of the distinguishing features that scientists use to divide them into subgroups (**LW 4.1**).

The students will be able to:

- describe special features of common sea mammals that help them to stay alive, for example, their feeding structures and strategies (**LW 3.2**);
- investigate how whales and other sea mammals give birth to and care for their young (**LW 4.2**).

The students will be able to:

- discuss ways in which human activities have endangered Māui's dolphin and the southern right whale and describe how the remaining populations could be protected **(LW 3.3);**
- describe variability among individual whales and discuss how and why scientists record their identifying features **(LW 4.3**).

The students will be able to:

- discuss ways in which scientists research the habitat requirements of dolphins and whales and then discuss other types of knowledge that help people to plan for the conservation of these animals **(LW 3.4)**;
- discuss ways in which scientists work out what and how whales and dolphins eat and discuss how that type of knowledge helps people to plan for the conservation of these animals **(LW 4.4)**.

Down for the Count

Possible Achievement Objectives

Mathematics

Statistics

- Plan a statistical investigation arising from the consideration of an issue or an experiment of interest (Statistical investigations, level 4).
- Collect appropriate data (Statistical investigations, level 4).
- Choose and construct quality data displays (frequency tables, bar charts, and histograms) to communicate significant features in measurement data (Statistical investigations, level 4).
- Report the distinctive features (outliers, clusters, and shape of data distribution) of data displays (Interpreting statistical reports, level 4).
- Make statements about implications and possible actions consistent with the results of a statistical investigation (Interpreting statistical reports, level 4).

Links to the Number Framework

Strategies

Stage Seven:	Advanced Multiplication and Division
	Early Fractions, Ratios, and Proportions
Stage Eight:	Multiplication and Division of Fractions and Decimals
	Advanced Fractions, Ratios, and Proportions

Knowledge

Stage Seven:	Advanced Multiplicative
Stage Eight:	Advanced Proportional

Developing the Ideas

Key Terms and Concepts

Together with "A Tragedy at Sea", "Down for the Count" could lead into discussion and activities relating to accurate population surveys. After the reading, point out that many population surveys involve **sampling** – the collecting and analysing of data from only a proportion of the population and the extrapolation (extension by inference) of this information later to cover the entire population. The students need to understand that sampling is much more efficient in time and energy than measuring the entire population. However, it is also very important to note that all sampling involves potential error. With Māui's dolphins, the ecologists needed to establish the exact number of dolphins. Rather than sampling the population, they attempted to count all the individuals. This approach involved potential error because they could have missed some dolphins or counted them twice, but the methodology aimed for results that were as accurate as possible.

Through follow-up discussion, you could promote the students' understanding and use of some key statistical terms:

Population: All the individuals of the group you are interested in. (In this case, the ecologists were dealing with the entire world population.)

Sample: A group that is selected (usually randomly) from the population and studied. The data obtained from the sample is used to make predictions about the whole population. This is why it is very important to pick a sample that is **representative** of the population.

Random: Unaffected by bias. For a sample to be random, each member of the population must have the same chance of being selected.

Bias: A factor that makes a sample unrepresentative in some way. A sample is said to be biased when every member of the group did not have exactly the same chance of being picked for the sample. In order to illustrate bias, you could ask the students to consider a class-member survey of how large they think your writing should be on the board. Ask them which of the following samples is the most representative: the 8 students nearest the front [approximately 25 percent]; the 8 students nearest the back [approximately 25 percent]; the 8 students nearest the middle [approximately 25 percent]; or 8 students selected at random from all around the classroom [approximately 25 percent]. The students should realise that the last sample is the only representative one. It will yield more accurate results because it is random.

A Sample versus a Census

Discussing the design of different types of survey will get the students thinking about planning a statistical investigation. Most importantly, they should consider some of the pitfalls associated with collecting representative data. Include in this discussion the differences between sampling a population and undertaking a census. (In a census, all members of the population are investigated.) While an accurate census can provide the most accurate data, the difficulties of such an approach are often considerable. Such difficulties include the impracticality of locating all the members of a population as well as time and budgetary constraints.

To reinforce these points, ask the students to think of situations where either a census or a sample would be better and make a list of these on the board. (For example, if you were planning a family holiday or an end-of-year class celebration, it would be practical to survey all the opinions of all interested individuals, but if you were investigating the television viewing habits of 11-year-olds, a representative sample would be the only practical option.)

Further Activities

Counting Mobile Animals or Objects

The next step might be to look at the difficulties of counting mobile individuals. In "Down for the Count", the main concern was that dolphins had been missed or that the same animals had been counted twice. To address these concerns, the ecologists systematically moved through the territory and tried to get to each new sector quickly. To check their accuracy, they double-counted the dolphins from a hilltop viewpoint. From this investigation, they accurately calculated the proportion of individuals missed in on-the-water surveys. (An alternative method would have been to tag those animals that had already been counted. However, this approach can harm or traumatise some animals.)

The students could develop their own methods for counting mobile animals or objects. Depending on the school environment, they might count ants, birds, students in the playground at break, or leaves floating in a pond or stream. Divide the class into groups and get each group to count the number of objects or animals in a certain area. If the results vary, which is highly likely, discuss ways in which the various results could be used to accurately estimate the number in that area. The students may well suggest averaging the results from all the groups, but was an averaged, multiple census the best way to gain this information? Perhaps a sampling method would have been more practical and accurate. At this point, you could discuss possible methods of sampling a population.

Using Quadrats

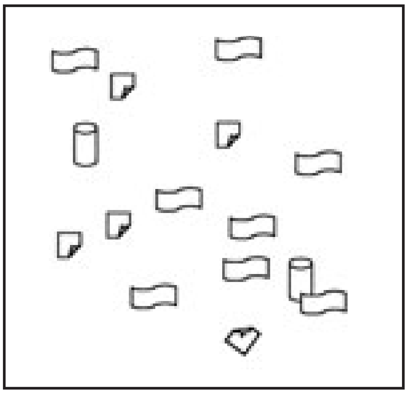
Numerical Tallies

A common method for population surveying involves quadrats, which are randomly placed, usually square sectors within which a full count is made. Quadrats can be used in either a sample or a census. For example, the scientists in "Down for the Count" used quadrats to help organise their census. Working in groups, the students could experiment with different ways of counting or estimating the numbers of a particular animal, plant, or object to see whether their results vary.

Quadrat size depends on what is being studied. For small plants such as lawn species, a quadrat from 100 to 1000 cm^2 would be suitable.

If much of the school's outside space is paved, the students could count types of litter or even chewing gum within large quadrats. The following example shows a litter survey within a large quadrat.

Objects	Sweet wrappers	Packets	Cans
Tally	卌	卌 |||	||
Number	5	8	2

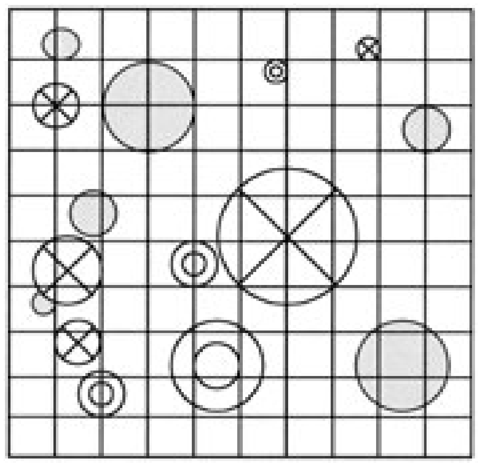


Ground Cover

In the case of plants, if the zone covered by a spreading plant is large or if it is difficult to determine how many individual plants are in a single large clump, it may be better to look at area coverage.

Plant	●	⊗	◎
Number of squares	21	26	16

In this method, the quadrat is divided into 100 equal squares. (Opting for 100 squares allows for quick percentage calculations.)



There will be a margin of error because even if only a small proportion of a square has the plant in it, it is counted as a full square. These sorts of error even out with an increasing number of samples. The number of samples necessary for gaining an accurate picture is dealt with under the heading How Much Is Enough?, later in these notes. However, rather than relying on numerous samples to even out the error, an investigator might decide to count only those squares that are at least 50 percent covered.

While useful, particularly when recording plants, this investigation indicates only the proportion of the various species – even if you were to count the number of individuals within each quadrat. To estimate population numbers, you would need to find out how many of your quadrats would fit into the entire territory and use that number as a multiplier.

Using Line Transects

Another common method of sampling involves line transects. Have the students mark a 20-metre piece of string every 50 centimetres or so and then lay it on the ground. They should then place a stick into the ground at the marked points and record any object touching it.

Quadrats may be used in conjunction with line transects. With a long transect, a quadrat reading can be taken at even or random intervals along the length of string.

Presenting the Results

Results from these samples could be presented as bar graphs for the counted data or histograms for the measured data. Pie graphs or dot plots could also be used. Note that there is no point in graphing data for the sake of it. There should be a clear purpose. For example, people often display their data in ways that will help them to recognise patterns and trends.

Whatever the subject, methodology, or display chosen, encourage the students to make statements about the results. For example, "Sweet wrappers are the most common litter in the playground." Also encourage them to use the results as the basis for action. For example, "We should design anti-littering posters for the school shop and problem areas of the grounds. From our sampling, we've discovered that people drop lots of sweet wrappers in the playground. So part of the posters' message should be that because sweet wrappers are small, people think it's OK to chuck them away – but if everyone thinks like this, wrappers soon build up into a real litter problem."

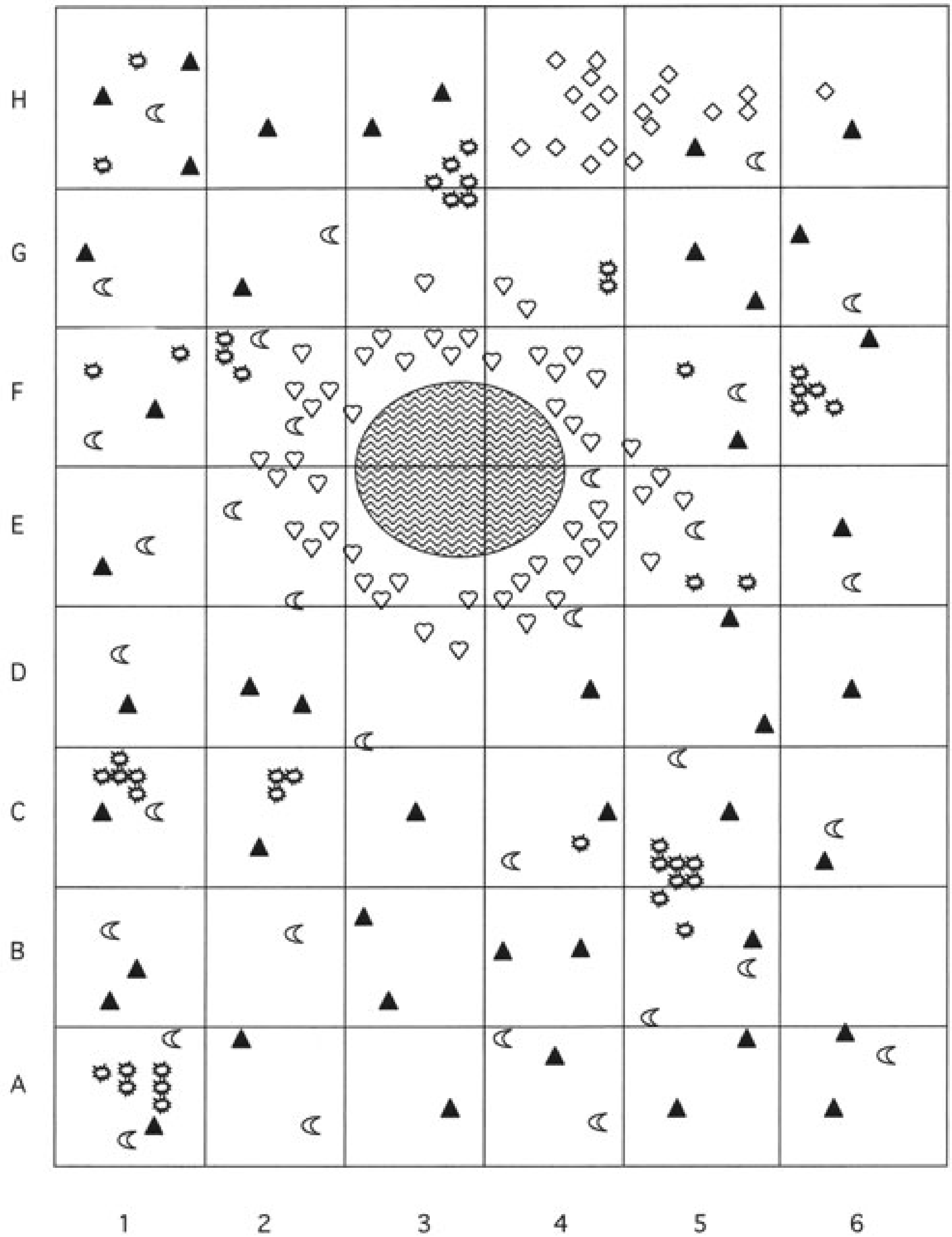
A Large-scale Community Study

Although the previous activities are useful on their own as an introduction to sampling and statistics, they could also be combined with a biological community study and linked with "Wonderful Water", also in this issue of Connected. At the planning stage of such an investigation, discuss ways of gaining a representative (unbiased or random) sample. As discussed, ecologists often achieve an unbiased sample by using line transects to determine quadrat placement. They can also place a grid over a map of the survey area and randomly choose grid references on which to lay the quadrats. Random numbers can be generated by a computer or a scientific calculator to give grid references; the grid references could be drawn from a hat; or a small object could be tossed onto the map.

Activity: How Much Is Enough?

It is very important to consider the number of samples needed for an accurate picture to emerge. Methods to resolve this differ, but they usually involve defining a minimum percentage cover. The following exercise will help the students to understand the issue.

The following diagram has five different shapes representing five different types of organism in an area of land surrounding a pond of water.


H
G
F
E
D
C
B
A
1
2
3
4
5
6

The actual numbers of the organisms are:

☾= 32 ; ▲= 46 ; ♡= 51 ; ◇= 19 ; ✹= 46

That means their percentages (to the nearest whole number and adjusted to add up to 100) are:

☾= 16% ; ▲= 24% ; ♡= 26% ; ◇= 10% ; ✹= 24%

Give the students this data or have them work it out for themselves. They should then list all the grid references on a sheet of paper and cut them out individually so that there are 48 small pieces of paper, each with a unique reference. They should then draw one reference from a hat, count the number of different organisms in the quadrat it represents, and record both the total number and the percentage of each species. In order to avoid counting any quadrat twice, the students should set the reference aside rather than returning it to the hat. They should then repeat the procedure.

After the second sample, ask them to work out the accumulated count and percentage for each species, recording the results on a tally chart. They should repeat the sampling until the accumulated percentages begin to match the actual data.

Grid Quadrats	☾ no./%	▲ no./%	♡ no./%	◇ no./%	✹ no./%
2E	2/29		5/71		
2E, 5C	3/20	1/7	5/33		6/40
2E, 5C, 5H	4/16	2/8	5/20	8/32	6/24
etc					

How many trials are needed to reach a point where further samples do not increase the accuracy of the findings? Does the number of samples needed depend on how evenly distributed the various species are? If necessary, point out that the organisms in this trial were very unevenly clustered. A large number of trials are needed because of this. In particular, the species represented by the diamonds is found in only three quadrats, which are themselves close together in the top right area of the grid. Because of the very clustered distribution, a full census or a sample involving a high proportion of the territory would be advisable.

How many samples do you think would be needed if you were investigating an area in which the five species were very evenly distributed rather than clustered? The students should realise that if the organisms were very evenly distributed, only one or two samples would be necessary. In such an instance, a sample rather than a full census would be satisfactory.

Make sure the students understand that this exercise is designed to show them how long-run sampling becomes more and more accurate as the number of samples increases. In this exercise, the students have carried out a full census first to determine reality and then repeatedly sampled until that reality emerged from the data. The exercise reflects what Kirsty and her colleagues did with their double count. The person stationed on the hill knew exactly how many dolphins were in the water, and this information was used to determine the error rate of the on-the-water counts.

Links to Figure It Out

Many of the activities in the following books introduce students to the planning of statistical investigations, the collection of data, and reporting. The accompanying teachers' notes discuss the concepts and methods involved.

Statistics: Book One, Years 7–8

The student activity Collect and Reflect (pages 6–7) and its accompanying teachers' notes explore statistical investigations and ways of displaying data. Channel Surfing (page 16) and its accompanying teachers' notes explore populations, censuses, and sampling.

Statistics: Book Two, Years 7–8

Social Sounds (page 1) and its accompanying teachers' notes explore populations, surveys, censuses, samples, bias, randomness, and representativeness.

Wonderful Water

Possible Achievement Objectives

Mathematics

Statistics

- Plan a statistical investigation arising from the consideration of an issue or an experiment of interest (Statistical investigations, level 4).
- Collect appropriate data (Statistical investigations, level 4).
- Choose and construct quality data displays (frequency tables, bar charts, and histograms) to communicate significant features in measurement data (Statistical investigations, level 4).
- Make statements about implications and possible actions consistent with the results of a statistical investigation (Interpreting statistical reports, level 4).

Measurement

- Carry out measuring tasks involving reading scales to the nearest gradation (Estimating and measuring, level 4).
- Design and use a simple scale to measure qualitative data (Estimating and measuring, level 4).

Science

Planet Earth and Beyond

- 3.4: Justify their personal involvement in a school- or class-initiated local environmental project.

Links to the Number Framework

Strategies

Stage Seven:	Advanced Multiplication and Division
	Early Fractions, Ratios, and Proportion
Stage Eight:	Multiplication and Division of Fractions and Decimals
	Advanced Fractions, Ratios, and Proportions

Knowledge

Stage Seven:	Advanced Multiplicative
Stage Eight:	Advanced Proportional

Developing the Ideas

Prior Discussion

The notes for "Down for the Count" describe ways in which students can learn about sampling ecological communities. Such sampling yields quantitative results. "Wonderful Water" can build on this work by showing how statistical investigations can also yield qualitative results, for example, reliable indications of a stream's "health".

Before reading "Wonderful Water", the students could discuss possible indicators of healthy and unhealthy streams. Then the discussion could shift to ways in which streams become unhealthy. A major factor affecting stream health is the "watershed", which is the area of land that contributes water to the stream. Because water often enters a stream after having travelled above or below the ground, land pollutants such as manure or fertilisers may wash into it.

The students could then discuss the sorts of things that might end up in streams drawing from different watersheds. Working in groups, they could list some of the things that they think might be found in the water of a stream running through a forest, a car park, the back of a garden, a farm, or an alpine region.

Carrying out a Stream Survey

Background Knowledge

After reading "Wonderful Water", the students could undertake their own stream survey. Before doing so, they could find out more about local-government water-conservation initiatives in your region. For example, information about the Take Action for Water programme can be found on the Wellington Regional Council's website at **www.wrc.govt.nz/TA/water/index.cfm**

Ideally the students should survey more than one stream to allow comparisons between various indicators of stream health. Alternatively, they could work with a class from a school in another area and use appropriate information technology to exchange data.

The students should find out a little about their stream before undertaking any sampling. For example, a web search or map study could reveal major types of land use in the vicinity.

As well as familiarising themselves with their stream's watershed characteristics, the students could measure and record its width and depth. The composition of the stream bed may also be important.

Macroinvertebrates

In the story, the students begin by studying the macroinvertebrate population. These animals are often referred to as “indicator organisms” because their type and number indicate stream health. Mayfly and stonefly larvae are found in only very healthy waterways; caddis fly larvae and crane fly larvae indicate that a stream is in good health; whereas the presence of only water boatmen, back swimmers, snails, midges, and worms in reasonable numbers indicate water of poor quality.

The story refers to ratings of “excellent”, “good”, “fair”, and “poor”. To increase the potential for applying simple statistical analysis to their survey, the students could research appropriate numerical values that could be assigned to these ratings. They could then determine a score above which a healthy stream is indicated.

Temperature

The students in the story then go on to look at temperature. The Wellington Regional Council suggests the following classifications for temperature.

Below 15°C	Excellent
15–18°C	Good
18–20°C	Fair
Above 20°C	Poor

Other Indicators

The students should then look at the other aspects described in the story – algal growth, water colour, water clarity, water smell, stream cover, and streamside erosion. For each factor, a group of students could develop specific criteria for the Excellent-to-Poor rating system. By drawing together the results of all the groups’ research, the class could develop a comprehensive recording form like that on page 17.

The students in the story worked out how to assemble and use the turbidity tube (also known as a clarity tube) without teacher instruction. From the description of the turbidity tube’s components, you could ask your students to do the same. To use a turbidity tube, you fill it with stream water and hold the disc magnet against the inside of the tube so that the disc is positioned at right angles to the side of the tube. You then place the plain magnet on the outer surface of the tube so that the two magnets hold each other firmly against the inner and outer surfaces of the tube. Seal the open end of the tube and hold it horizontally while someone else glides the outer magnet back and forth along the gradations of 1 to 100 centimetres. The outer magnet will drag the inner magnet and disc with it. You can work out the centimetres of visibility by stopping the magnet at the point on the scale where its outline becomes clear when viewed through the end of the tube. Instructions for making a turbidity tube can be found on the Royal Society’s National Waterways Project website at:
http://nwp.rsnz.org/content/waterquality_gotthedirt.doc

Calculating the Speed of Flow

The students may also wish to determine how quickly the water is flowing. There are several ways of doing this. For example, the students could record the time it takes an orange to travel a known distance such as 5 metres (or further if the water is flowing very quickly), repeat the trial a number of times, and find the average. By dividing the number of metres travelled by the time taken, the students can work out the flow rate in metres per second. (People sometimes carry out this activity with a floating stick, but water flow is faster at the surface than it is further under and, because an orange sits lower in the water than a stick, it travels less quickly and indicates a velocity that is closer to the average.)

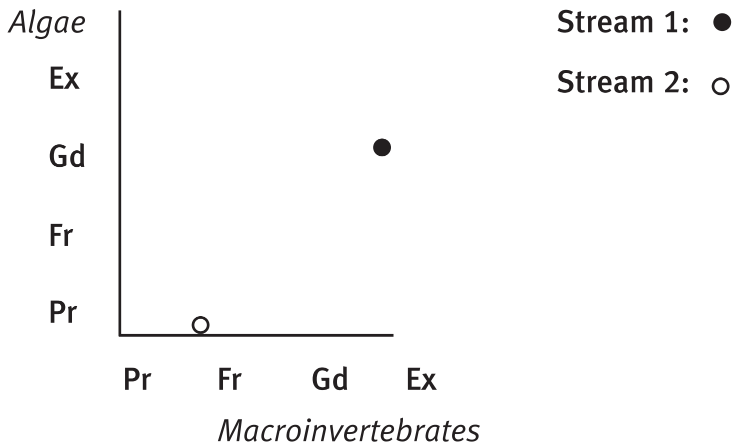
Stream Survey Form

Approximate stream width: **Approximate stream depth:**	**Comments on surrounding area:**
Macroinvertebrate count: Mayflies: Snails: Water boatmen: Midges: Stoneflies: Worms: Back swimmers: Caddis fly larvae: Crane fly larvae: Rating:.................	
Water clarity: 80–100 cm.................................. Excellent 50–80 cm.................................... Good 25–50 cm.................................... Fair 0–25 cm...................................... Poor	**Stream bed material:** Silt Cobbles Mud Boulders Sand Rock Gravel
Water colour: Clear..Excellent Slightly milky.............................. Good Murky or muddy..........................Fair Brown, black, oily, scummy, or foamy.......................Poor	**Average water speed:**
Water smell: None.. Excellent Slightly musky............................ Good Some odour.................................Fair Strong odour............................... Poor	**Water temperature:** Below 15°C.................................. Excellent 15–18°C...................................... Good 18–20°C...................................... Fair Above 20°C................................ Poor
Algal growth: Thin growth on rock.................... Excellent Moderate film or mat...................Good Thick, dense mat......................... Fair Long, thick filaments...................Poor	
Stream cover: Number of trees covering the stream: Many... Excellent Some...Good Few..Fair None...Poor	**Overall Rating:** **Excellent** **Good** **Fair** **Poor**

Reporting

Once all the data has been collected, the students could record and display their results in a variety of ways. For example, each group could write an environmental report on the stream, including a description of the area, appropriate graphs, and/or tables of the results. If comparison with another stream is possible, the students could display both sets of data in a similar way and draw conclusions about the comparative health of each stream. Encourage them to back up their statements with numerical or graphical evidence.

Scatter diagrams could be used to show relationships between aspects of the streams' health. For example, the following diagram shows that stream 1 had an excellent macroinvertebrate reading and a good algal identification, whereas stream 2 had a fair macroinvertebrate reading and a poor algal rating.



Other pairs of factors, such as macroinvertebrate numbers and water temperature, could also be graphed and discussed. Pie graphs showing percentages of the different types of macroinvertebrates would also be useful in showing community differences.

If there is a stream close to your school, the students could make comparisons through the seasons to investigate whether any factors are affected by temperature and rainfall.

Further Activities

Other Focuses for Research and Action

The students could extend their study to include a report on the effects of fertilisers and chemical spraying on stream water quality. There has been extensive world-wide research on this issue, and information about it can be found on the Internet.

If the students have been able to determine a cause for the pollution of their stream, they could investigate ways of cleaning up the area and raising public awareness of water quality issues. In developing their strategies, the students could consult with local experts, such as regional council staff.

The students could design another form of environmental survey to assess the effects of pollutants on a community. For example, they could investigate the environmental effects of a rubbish dump on the surrounding environment, including an increase in the number of seagulls and other scavengers as well as chemical leaching.

Links to Figure It Out

Many of the activities in the following books introduce students to the planning of statistical investigations, the collection of data, and reporting. The accompanying teachers' notes discuss the concepts and methods involved.

Statistics: Book One, Years 7–8

The student activity Collect and Reflect (pages 6–7) and its accompanying teachers' notes explore statistical investigations and ways of displaying data.

Statistics: Book Two, Years 7–8

Testing Times (pages 12–13) and its accompanying notes explore bivariate data. Suspect on Foot (page 16) and its accompanying teachers' notes explore bivariate data, trends, and correlation.

Eco-friendly Inventions

Possible Achievement Objectives

Science

Planet Earth and Beyond

- 3.4: Justify their personal involvement in a school- or class-initiated local environmental project.
- 4.4: Investigate a local environmental issue and explain the reasons for the community's involvement.

Living World

- All the achievement objectives in this strand help students to develop awareness of, sensitivity to, and knowledge and understanding of the natural environment.

Material World

- 4.4: Investigate the positive and negative effects of substances on people and on the environment.

Technological Areas

Biotechnology

Structures and Mechanisms

Materials

"Eco-friendly Inventions" is designed to stimulate students' awareness and ideas at the beginning of a technology unit and/or an environmental education unit. The following notes are divided into two broad sections: Environmental Education Notes and Technology Notes. There is, however, potential for you to combine ideas from both sections and develop a cross-curricular unit that encompasses technology, environmental education, and science.

The environmental education section includes a fun activity through which students can explore the interconnectedness between people's actions and the environment. An example of an environmental action plan is also provided to show the recommended general structure of such a plan and to give you an idea of the kind of content that your students might develop. For detailed advice about developing and implementing a cross-curricular environmental education programme, see the Ministry of Education's *Guidelines for Environmental Education In New Zealand Schools* (Learning Media, 1999).

The technology notes suggest an initial discussion in which the students consider the general range of eco-friendly alternatives to toxic pesticide use. The further activities that follow are divided into three main sections: Developing Knowledge and Understanding (which includes scientific investigations); Choosing an Outcome to Pursue (in this instance, an eco-friendly pest control solution); and The Technological Process (which includes focusing, planning, implementation, and evaluation).

Environmental Education Notes

The aims of environmental education, outlined on page 9 of *Guidelines for Environmental Education In New Zealand Schools*, are for students to develop:

- **awareness and sensitivity** to the environment and related issues;
- **knowledge and understanding** of the environment and the impact of people on it;
- **attitudes and values** that reflect feelings of concern for the environment;
- **skills** involved in the identification, investigation, and resolution of environmental issues;
- a sense of responsibility through **participation and action** as individuals or as members of groups, whānau, or iwi.

The Specific Learning Intentions

The students will be able to:

- research and evaluate eco-friendly methods of controlling weeds and pests in their home or school environment – which may involve them adopting and combining other people's ideas and strategies to suit their own needs, contexts, and values (knowledge recycling);
- develop strategies for persuading others to reduce toxic chemical use in particular environments – which may involve them evaluating other people's practices, values, and priorities and, on the basis of this evaluation, developing and promoting appropriate options for them.

The Key Ideas

- Students can be actively involved in improving the quality of their environment.
- There are non-toxic methods of controlling pests and weeds.
- Non-toxic options may cost more than commercial pesticides, but they are often better for the environment in the long term.

Developing the Ideas

Introductory Activity: Caterpillar Connections

(Adapted with permission from the Web of Life activity on page 95 of the *Enviroschools Kit*, Hamilton City Council, 2001)

What You Need

- One chair for every two participants
- Laminated effects-and-consequences cards (provided as a copymaster below)
- Coloured pegs
- Balls of string

What You Do

- Arrange the chairs facing inwards in a circle.
- Ask the participants to pair up. One person in each pair sits on a chair and the other person stands behind them.
- Give an effects-and-consequences card to each seated person.
- Give four of the standing people a ball of coloured string each.

- Each seated person reads aloud the phrase written on their card and then pegs the card to their chest.
- Nominate one pair to start the matching-up process. Both partners identify another phrase that they can link with their own. For example, "Too many green caterpillars are on the cabbages." —› "Fewer cabbages grow to a good standard." The seated partner holds on to the free end of the string while the standing partner unravels and passes the ball of string to the standing partner of the new pair.
- The new pair repeat the procedure by identifying another link. For example, "Fewer cabbages grow to a good standard." —› "Grower gets less money."
- Continue the procedure until no more links can be identified.
- At any time, other pairs could begin the process at different points in the circle with different coloured string. (It is manageable to have up to four balls of string in play at once.)
- Eventually, a web showing all the relationships is created. Discuss the interconnectedness of the environmental factors. Ask the students to summarise the likely consequences of a big increase in the number of caterpillars. Ask about the likely effects of another change, such as a significant increase or decrease in rainfall.

What You Look For

- Can the students identify key cause-and-effect relationships?
- Can they infer the consequences of changes in key environmental factors?

Phrases for Laminated Effects-and-consequences Cards

Too many green caterpillars are on the cabbages.	Cabbages can't be sold at the market.	Grower has less money.	Workers lose jobs.
Grower can't afford pesticides to get rid of caterpillars.	Soil contaminated.	Fewer cabbages grow to a good standard.	Workers move away from region.
Grower has to use more pesticide to get rid of caterpillars.	Costs of growing cabbages increase.	Fewer kids are at school because families have moved away.	Grower uses organic methods to control caterpillars.
A large number of healthy cabbages are grown.	Pesticide kills "good" organisms as well as pests.	Other pests come into the area.	More jobs for workers.

At the end of the exercise, focus on the organic control card. Ask the students how the grower could control caterpillars without using pesticides. Gather the students' ideas and read them "Eco-friendly Inventions", pausing for discussion whenever the text reflects the students' ideas. Alternatively, the students could read the article themselves and discuss links with their own ideas when everyone has finished.

Further Activities

An Environmental Action Plan

Developing an action plan is an essential step in an environmental education unit. The process of developing and implementing the action plan is not linear. The students will probably need to revisit many of the sections more than once as the unit proceeds.

Example Action Plan: Eco-friendly Pest Control

This example is based on the suggestion that the class should be responsible for eco-friendly pest control in the school gardens.

Eco-friendly pest control in the school gardens

What skills do we need?

We need the following skills:

- research and investigation (science, technology, and social studies);
- information analysis;
- communication;
- problem-solving.

Who makes the decisions?

We need to:

- find out who decides about the gardens and how they do so;
- talk to the gardener or caretaker about establishing eco-friendly pest control in the school;
- raise the awareness of the decision makers and the school as a whole;
- discuss the issues with the principal, teachers, and board of trustees.

ACTIONS

- **Communicate our vision for eco-friendly pest control in the school.**
- **Find out what the stakeholders (principal, gardener, teachers, and students) think about our ideas.**
- **Gather other ideas from the stakeholders.**
- **Develop and carry out an eco-friendly pest control programme that includes an education component designed to encourage others to adopt non-toxic strategies.**

We can develop awareness by:

- walking around the school and studying all the gardens;
- reading "Hukanui: Enviroschool", *Connected 3 2002*;
- reading Suzuki and Vanderlingen's *Eco-Fun: Great Projects, Experiments, and Games for a Greener Earth* (Greystone Books, 2001);
- talking to parents and grandparents who have gardens;
- visiting Michael's grandad's garden;
- inviting Mr Brown from the local nursery to talk to us;
- inviting Mrs Green from the Permaculture Society to talk to us.

We can explore different attitudes and values by:

- investigating the existing methods of pest control in the gardens;
- investigating eco-friendly alternatives;
- carrying out a survey to find out what the stakeholders think;
- using large charts to report the results of the survey to all the stakeholders;
- discussing all the possibilities and deciding on an "eco-friendly pest control plan" for our garden.

Identify and enhance knowledge and understanding by:

- reading "Hukanui: Enviroschool";
- listening to guest speakers;
- carrying out science investigations;
- writing a report about the visit to Michael's grandad's garden;
- writing a school newsletter article about eco-friendly pest control;
- drawing pictures of different eco-friendly pest-control methods and displaying these in the school hall.

Evaluation and Reflection

After the programme is completed, reflect on what has happened.

- Did the students achieve the vision?
- What actions were successful? Why?
- What actions were not successful? Why not?
- What could have been done differently to achieve the vision?
- What could be done in the future to achieve or maintain the vision?

Technology Notes

The Specific Learning Intentions

The students will be able to:

- explore the nature of environmental issues with a focus on people's differing attitudes and values;
- develop potential solutions to an identified environmental problem;
- critically evaluate their technological solutions to decide whether they meet the identified specifications.

The Key Ideas

- Our attitudes and values affect the decisions we make in our technological practice.
- Our lifestyle choices can significantly reduce our impact on the environment.
- Environmentally friendly strategies and products for controlling weeds, pests, and diseases are well publicised and commercially available.
- It is also possible to develop and use our own strategies and products.

Developing the Ideas

Technology and environmental education can be combined very effectively in an integrated teaching programme. In this instance, the awareness-raising and knowledge-gathering phases of an environmental action plan address aspects of Strands A and C of *Technology in the New Zealand Curriculum*. When the students identify the stakeholders' opinions and values, they address aspects of Strand C. In developing and implementing their action plan, the students may address aspects of Strands A, B, and C. During this phase, their technological practice may centre on developing their own solutions, such as pest traps or barriers, nesting boxes or feeding stations to attract birds, non-toxic spays, or spray nozzles and wind barriers that help to restrict potentially harmful sprays to their target.

Initial Research and Discussion: a Range of Eco-friendly Alternatives

After the first reading, the class could discuss how and why people's environmental attitudes and values have changed in recent times. Changing attitudes have influenced the design of technological outcomes. Through playing Caterpillar Connections (suggested in the environmental education notes), the students could explore the interconnections between technological practice, the environment, and society.

A key science concept that underpins many eco-friendly outcomes is that we can control pests and weeds by understanding the ways in which they are affected by and respond to their environment. This understanding underpins companion planting, traps, non-toxic chemical alternatives, natural predators, and mulching. In order to stimulate the students' ideas for their own technological practice, you could lead a classroom discussion about this general range of options.

Companion Planting

Some plants release chemicals that inhibit the growth of other plants or deter animals. This is the basis of companion planting. Common examples of biological inhibition or deterrence include:

- planting nasturtiums, garlic, nettles, or basil near roses to control aphids;
- planting clumps of chives around apple trees to prevent fungal diseases;
- planting herbs around a vegetable garden to prevent caterpillars getting to the vegetables;
- planting marigolds among vegetables such as lettuces, beans, and tomatoes to protect them from insects and to stop dogs urinating on the garden.

Traps

Insects respond to environmental stimuli, such as light intensity, colour, temperature, and chemicals. Some insects seek shelter in cool, dark places. If you put short sections of old garden hose or bamboo in the garden, earwigs will crawl into them. They can then be collected and disposed of. (This concept is explored in the following activity, Slater Sleuth.) Likewise, if you lay cabbage leaves or large pieces of citrus peel on the garden at night, snails will gather under them. Night-flying insects can be trapped in a bucket of water left under an outside light, and shallow containers of sugar-water, honey, beer, or dried yeast may also trap many pests while you sleep. Fruit flies are attracted to yellow light. As "Eco-friendly Inventions" describes, these pests can be trapped on sticky strips of bright yellow plastic.

Non-toxic Chemical Alternatives

Many pests and weeds can be controlled with non-toxic chemicals. Aphids can be washed away with a good blast of cold water after spraying with soapy water. A spray made from garlic, nettles, basil, or wormwood is also effective. Sprinkling pepper on damp leaves deters caterpillars. You can deter fleas by rubbing squashed fennel leaves over your hands and running them through your dog's fur.

Mulch

You can inhibit weed growth by excluding light. This can be achieved by covering the soil with organic material such as grass clippings, straw, paper, or cardboard.

Natural Predators

Predatory birds and insects will help control pests and weeds if you can attract them to or release them into your garden. A ladybird can eat more than four hundred aphids a week. Silver eyes (or wax eyes) eat large numbers of aphids and caterpillars. (Up to 50 percent of their diet is made up of insects.) Starlings eat grass grubs and are attracted to the garden if you provide nesting boxes.

Knowledge-building Activities

If you wish the students to focus on research, you could limit the previous discussion to developing a list of general headings that cover the range of options. You could then ask the students to research the details themselves. This could be done through books and the Internet, but direct contact with experts would be ideal. For example, the students could carry out some of the following knowledge-building activities.

- Research natural pest-control sprays by searching the library or Internet. Also, local organisations such as the orchid society may provide recipe booklets for natural sprays.
- Visit a garden shop to survey the range of commercially available natural sprays. Read the labelling to identify common ingredients and see what sort of warnings are given. Some "natural" sprays are nonetheless toxic.
- Visit an organic produce outlet to identify local suppliers of organic vegetables. Make contact with an organic grower, develop a list of focus questions, and visit their farm or orchard to explore organics in action.
- Traditional Māori horticulture included natural systems to manage pests and diseases. Talk to local kaumātua to find out more.

Further Activities

Developing Knowledge and Understanding

During the focusing and planning phases, a selection from the following activities could help the students to understand key issues and come up with starter ideas for their own solutions. The first two activities could be carried out together because if you wish to trap an animal, you need to understand its behaviour.

Exploring Animal Behaviour

The students could carry out (or observe a demonstration of) a science investigation into earthworm behaviour. They could then design similar investigations into the behaviour of invertebrate pests such as snails, aphids, or caterpillars. The investigation(s) could focus on the pest's preferred habitat conditions and food.

Worm Sleuth: Observation of Animal Behaviour
For activities that explore worm behaviour, see pages 100–104 of the Ministry of Education's *Making Better Sense of the Living World* (Learning Media, 2001). Use these activities as a model for the students' own, self-directed investigations.

A Self-directed Investigation
After the students have completed a selection of worm behaviour activities, they could design their own investigations into the behaviour of snails, aphids, or caterpillars (perhaps with a focus on their feeding preferences and behaviours) and use their new knowledge to develop eco-friendly control strategies. For example, having completed their investigations, the class could pool the results and develop a control strategy that involves trapping, barriers and deterrent surfaces, or a combination of these and other approaches.

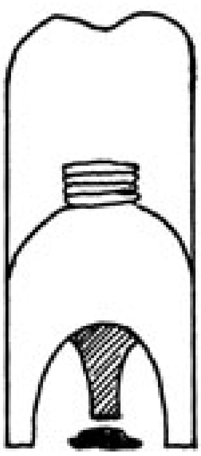
Researching and Evaluating Pest Traps

The students could make a simple flytrap from a PET bottle. They could then analyse the features that make the trap effective (using the Analysis of Functional Principles worksheet to structure this analysis). Later, they might decide to use the results to guide their development of new trap for a particular pest, whose anatomy, behaviour, and/or physiology will directly influence the trap's design.

For further information about the terms used in the worksheet, you could refer to pages 16 to 19 of the Ministry of Education's *Design and Graphics in Technology* (Learning Media, 2001). Included are notes about the key principles that underpin the functioning of products and systems and two student activities that explore them.

This flytrap analysis will give you a chance to use a standard product to explain the application of functions in design briefs. Students can analyse the product and think about how they could make their own outcome achieve or improve on these functions.

The following trap works because, after feeding on the bait, flies nearly always fly off in an upward direction. Because of this behaviour, they end up crawling through the bottle's funnel and into the upper chamber, from which it is almost impossible to escape.



A PET-bottle Flytrap

Analysis of Functional Principles

Functional Principles	Flytrap	My Eco-friendly Invention
User friendliness		
Fitness for purpose		
Strength		
Safety		
Cost		
Environmental friendliness		

Choosing an Outcome to Pursue

The following ideas are not intended as prescriptions for student practice. Rather, they are provided to give you an idea of the range of options. For example, after carrying out the previous knowledge-building and stimulus activities, the students might decide to:

- develop an environmentally friendly spray to control a pest in the home garden;
- develop a composting system to provide nutrients for home or school gardens;
- develop a worm farm to process school food waste then research the general characteristics of worm tea and develop their own recipe;
- develop a shield to protect sensitive plants from spray drift;
- develop a bug trap for a home or school garden;
- develop a nesting box or a feeding station to attract birds to a garden;
- develop a barrier that restricts pests' access to the plants in a home or school garden.

The Technological Process

Whatever outcome the students decide to pursue, the general technological process will involve the following key stages.

1. Developing the **brief**

2. **Planning** the process of developing the outcome

3. **Developing and evaluating** the outcome

1. The Brief

The students will need to develop a brief that:

- states what they intend to make and why;
- shows how the values of the stakeholders will be canvassed and taken into account;
- considers the possible environmental impact of the outcome;
- details the appearance and functioning of the outcome.

Understanding the Stakeholders' Values and Attitudes
The students should identify and interview the key stakeholders in order to understand other people's attitudes towards toxic insecticides and the values that underpin those attitudes. For example, they could survey how local consumers (including themselves), local retailers, and local growers feel about using toxic sprays to control horticultural pests and diseases. Later, the students could canvass the same people's views on their proposed alternative(s).

Writing Their Own Brief
With the students, identify the constraints that will affect the development of the outcome they have chosen to pursue. They will need to consider such factors as how much time they will have, what materials are available, the size of the outcome, and what it will have to be able to do. In short, the brief should describe what the students intend to make and why. Make sure that the brief clearly specifies the outcome's intended functions. Later, the students will be able to evaluate the outcome against these specifications. The students can build and modify the brief as they acquire more knowledge and skills during the unit – that is, the brief and the outcome develop concurrently as the project proceeds.

2. Planning

Good planning will guide the students during their practice and ensure that resources will be managed efficiently. The students should record how they intend to produce their outcome. This planning needs to be flexible enough to change as new ideas emerge or as unforeseen circumstances arise.

There are many useful planning tools. The students could select one or more of the following to guide their planning.

- Gantt charts (see later example)
- Timelines
- Flowcharts
- Lists
- Action planners
- Labelled diagrams

Planning Activities

The class could use the flytrap-making activity as a model to help them to plan their own project. Like the brief development, planning is a dynamic process associated with all aspects of the outcome's development.

- The students could discuss the previous list of planning tools and identify how each could have been used to help in the flytrap-making activity, especially if they themselves had been designing the trap from scratch.
- They could discuss the steps involved in making the flytrap, identifying the tools and materials that were needed. You could write these on cards and get the students to sequence them in flow-chart form, or they could reconstitute the information in another of the formats listed above.

- They could consider and discuss the process that they will pursue in their own project and create a detailed plan for developing their outcome. An important aspect of product development is research. Encourage the students to consider what they will need to know and how they will find it out.

3. Developing and Evaluating the Outcome

While prototyping and trialling their outcomes, the students will experiment and present their ideas to others for feedback. They should analyse the feedback and refine their outcomes. They may make more- or less-detailed models or mock-ups and evaluate these against the functions they specified earlier. The students' ongoing evaluation should involve them referring to the brief regularly to ensure that they are staying within the identified scope and fulfilling the specifications. (They could use the Analysis of Functional Principles worksheet when evaluating whether their prototype fulfils the functional specs.)

The students may be able to evaluate their outcomes by field testing them. The final evaluation should involve the key stakeholders whom the students consulted while developing their outcome.

Gantt Chart Example

This is an example of a Gantt chart. The shaded parts indicate the time within which you will need to complete parts of a job. By referring to a Gantt chart as your project progresses, you can make sure you're staying on schedule. Using a Gantt chart allows you to work out how long each step will take and to determine which steps need to be completed before or at the same time as others.

Tasks	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Carry out investigations								
Talk to stakeholders								
Analyse the investigations and discussions								
Make mock-ups								
Gather feedback								
Gather resources								
Prepare materials								
Assemble								
Carry out trials								
Evaluate								