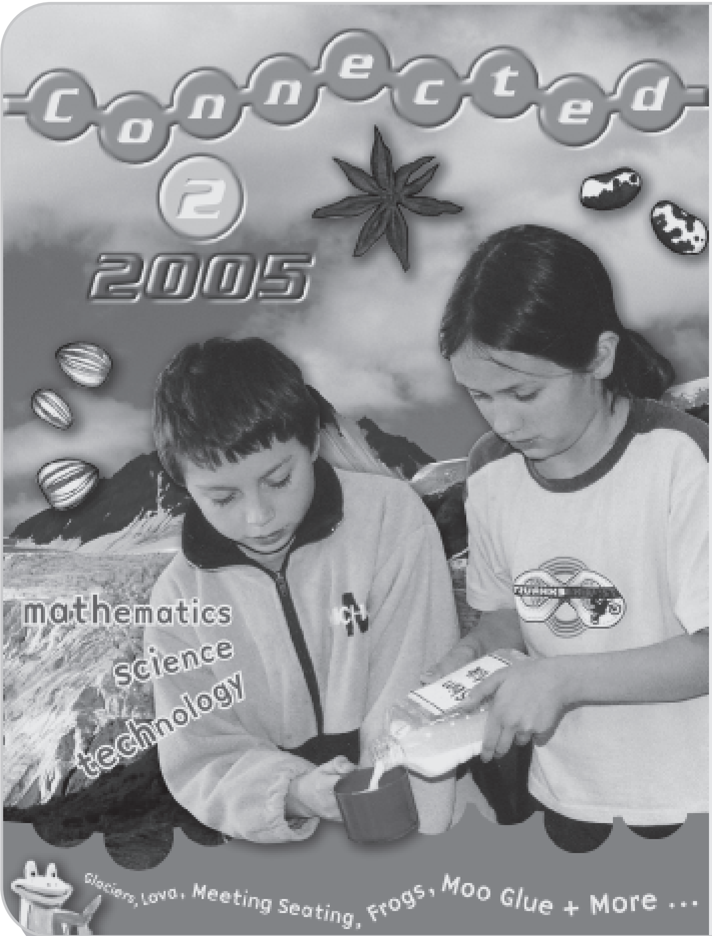
MINISTRY OF EDUCATION
Te Tāhuhu o te Mātauranga



Notes for Teachers

Connected 2 2005

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. Connected 2 is designed to appeal to years 4 to 6 students, working at levels 1 to 3, by reflecting their interests and experiences, expanding their knowledge and understanding, and engaging their imaginations.

General Themes in *Connected 2 2005*

The main themes in *Connected 2 2005* are glaciers and lava flows, enhancing outdoor environments, glues, and games of strategy.

1. Glaciers and Lava Flows

The suggested follow-up activity integrates "Creeping Along" and "Living on a Lava Flow" by encouraging your students to think about ways in which glaciers and lava flows are the same and ways in which they are different. To help develop the students' visual literacy, the activity invites them to think about how the same type of object (in this case, a glacier or a lava flow) can be shown in very different ways when a photograph is taken or a picture is drawn. To explore this idea, the students are asked to find pictures that best illustrate particular science ideas and then to explain their choices.

2. Enhancing Outdoor Environments

The suggested learning sequence will help your students to understand how the values, beliefs, and needs of both technologists and end-users affect the development of particular solutions. The students are asked to identify an area in the school grounds that they would like to enhance with the addition of a feature made from hypertufa. They will need to explore the values, beliefs, and needs of students and staff and use this information to plan an outcome that will make the area pleasant and restful for them.

3. Glues

The suggested learning sequence focuses on developing students' investigative skills within a context of deciding which is the best glue to use. Students often use the term "best" without defining what this means. An important part of the learning sequence is developing a set of criteria against which to judge various glues. Those criteria then become the basis for an investigation into which type of glue is best for a specific purpose.

4. Games of Strategy

The game described in "Pond Puzzler" can be played and explored at various levels of complexity, beginning with the 7-lily-pad version in the students' book. The students could play the game at home with their family or at school as a group or whole-class activity. However it is introduced, it will take students only a few games before they are certain that the person who starts has an advantage. The challenge then is to find and describe the winning strategy, explain why this strategy works, and then see whether the same strategy holds for an increased number of lily pads.

"Creeping Along" and "Living on a Lava Flow"

Possible Achievement Objectives

Science

Planet Earth and Beyond

- 2.1/4: Investigate easily observable physical features and patterns and consider how the features are affected by people.
- 3.1: Investigate the major features, including the water cycle, that characterise the Earth's water reserves.

Nature of Science

- 2.1: Use a variety of methods to investigate different ideas about the same object or event.

The Specific Learning Intentions

The students will be able to:

- use scientific observation skills when appraising visual images;
- select images to convey a simple science idea;
- compare lava flows with glaciers and develop a list of key similarities and differences.

The Key Ideas

- Glaciers and lava flows have some features in common and some that are different.
- Some visual images illustrate specific ideas about glaciers or lava flows better than others.

Developing the Ideas

The following activity integrates "Creeping Along" and "Living on a Lava Flow" by encouraging your students to think about ways in which glaciers and lava flows are the same and ways in which they are different. After they have read both articles, mention that there are many ways to convey these similarities and differences. The students are going to carry out an activity that focuses on the information we bring to and get from visual images. Discussing the following ideas will set the scene for this.

The ways in which we perceive such images shape, but are also shaped by, our existing ideas. To turn around a common expression, we could say, "I wouldn't have seen it if I hadn't believed it!" While this idea can be applied to many aspects of life, it takes on a Nature of Science focus when we apply it to observations we make to support science ideas we are exploring.

To help develop your students' visual awareness (or visual literacy), the activity invites them to think about how the same type of object (in this case, a glacier or a lava flow) can be "framed" in very different ways when a photograph is taken or a picture is drawn. The framing chosen by the photographer or artist may be accidental (for example, a spontaneous tourist snapshot) or very carefully considered (for example, the photographs and diagrams in science publications). In either case, any one image tells only a partial story.

What we see depends to a considerable extent on what we expect to see. Our theoretical ideas and cultural contexts help to "frame" our observations. The activity develops students' awareness of this by inviting them to find pictures that best illustrate particular science ideas and then to explain their choices.

Further Activities

Investigation: Lava Flows and Glaciers

What You Need

- Pairs of statement cards
- A collection of publications that include images of lava flows and glaciers (and/or access to the Internet as a source of images)

What You Do

- Collecting images is an important part of this activity. You could prepare by assembling a set of well-illustrated books and magazines to augment the photographs in the article. (The students will be able to access a much wider range of images if they also have access to the Internet and a colour printer.)
- Listed below are ten pairs of statements that compare glaciers with lava flows. Copy these statements, or others that you choose, onto sets of cards so that small groups can each select a pair of statements to explore visually.
- From the range of available images, the students should choose one of a glacier and one of a lava flow to best illustrate the comparison made in their pair of statements. Encourage them to talk about how their chosen images convey the science ideas on their card. Later, ask them to explain their choices to the whole class. If you have access to a colour printer or photocopier, they could reproduce the images to make a wall display.

What You Look For

- Do the students demonstrate understanding of the science ideas that their set of statements explores?
- Have they chosen images that appropriately illustrate those ideas?
- Can they explain how their choices illustrate the ideas?

Sample Statement Pairs

Glaciers are pushed along by their own weight, especially the weight of ice at the top.
Lava flows are pushed along as molten rock is ejected under pressure from a volcano.

We can see the movement of a glacier only over a long period.
We can see the movement of a lava flow over a few hours.

Glaciers break up rocks and make a lot of rubble.
Lava flows form sheets of new rock.

Glaciers flow down valleys and carve them into wide U-shaped spaces.
Molten lava flows down valleys and can fill them up when it cools to form solid rock.

Glaciers are very cold because they are made of ice.
Lava flows are very hot at first because they are made of molten rock.

Glaciers melt as they warm up.
Lava flows solidify as they cool down.

Glaciers advance or retreat, depending on the temperature.
Lava flows do not retreat. Rather, they stop and then slowly decompose.

When glaciers retreat, they leave an empty valley.
When a lava flow stops, it leaves solid rock.

No plants grow on a glacier, but they can eventually grow in the valley where a glacier has been.
After a lava flow has solidified, plants start to grow on it – but this takes many years.

Glaciers are often dirty on the surface, but the ice inside can glow white and blue.
Molten lava flows are often dark on the surface but the very hot rock inside can glow red and orange.

Some statement pairs will be easier to illustrate than others. For example, colour comparisons are relatively easy to illustrate, whereas it is not so obvious how to visually convey the temperature comparison. Similarly, changes of state require careful thought. What is the visual evidence that a glacier is melting? It could be a stream emerging from the snout, the empty space where a glacier has been, or time-lapse images showing a glacier's slow retreat. What is the visual evidence that a lava flow is cooling? It could be a change of colour and texture. It also could be that living things can now stand or grow on it.

A Simpler Version

If you are concerned that your students will have trouble with this activity because it is too unfamiliar, you could begin by giving them simple comparisons between glaciers or between lava flows.

Comparing Glaciers

Glaciers are found in different countries.
Some glaciers are longer and/or wider than others.
Some glaciers flow down steeper valleys than others.
Some glaciers are advancing and some are retreating.

Comparing Lava Flows

Lava flows occur in different countries.
Some lava flows swallow up inhabited land, whereas some do not.
Some lava flows are very recent, whereas some occurred a long time ago.
Some lava flows move more quickly than others.

Useful References

- *Volcanoes*, book 12 in the Ministry of Education's Building Science Concepts series (Learning Media, 2001), suggests activities that explore the causes and effects of different types of volcanic eruption. Specifically, Section 2, Activity 4: Volcanic Boil-ups explores fast-moving lava flows, which could invite a different set of comparisons of similarities and differences. For example, the low viscosity (resistance to flow) of very fast flowing lava is caused in part by the tiny gas bubbles that are all through it. Slow-moving lava lacks these bubbles. The different types of molten rock found in the lava flow also contribute to the speed at which it moves. For example, lava composed of molten basalt tends to spread slowly in big sheets.

- Activities 5, 6, and 7 on pages 28–30 of the Ministry of Education's *Making Better Sense of Planet Earth and Beyond* (Learning Media, 1999) explore the ejection of molten rock from volcanoes.

Room 5's Amazing Meeting Seating

Possible Achievement Objectives

Technological Areas

Materials Technology

Structures and Mechanisms

(See the Specific Learning Intentions for links to the relevant Achievement Objectives.)

The Specific Learning Intentions

The students will be able to:

- demonstrate their knowledge of the physical properties of appropriate materials, and techniques for their management, when developing technological solutions (AO 1–3, 5, 6a–d);
- appraise other people's technological practice and draw conclusions that help them to develop their own technological practice (AO 1–4, 6a–c);
- demonstrate knowledge of how the values, beliefs, and needs of technologists and end-users affect the development of particular technologies (AO 7, 8);
- develop a brief to ensure that the outcome meets the needs of all stakeholders and is appropriate to the physical and cultural environment (AO 5, 6).

The Key Ideas

The following aspects of technological practice, as exemplified in "Room 5's Amazing Meeting Seating", can be explored in a wide range of contexts and activities.

1. By consulting with experts and stakeholders, the students were stimulated to think beyond their own perceptions of what would be a "good idea".
2. Developing the brief was an ongoing process that allowed the students to come up with ideas for solving problems as they arose.
3. The students used their existing knowledge from other curriculum areas, especially the visual arts, when developing creative solutions.
4. By trialling and testing ideas through models and a small-scale prototype, the students identified the strengths and weaknesses of possible solutions.

Developing the Ideas

In order to focus students' minds on the important aspects of technological practice exemplified in "Room 5's Amazing Meeting Seating", you could discuss the following key ideas in the storyline.

1. The students in the article knew how the seat would be used, so they could discuss what they wanted among themselves, but they needed to call in experts such as an engineer and a kaumātua to help them work through the other issues. The students' ideas were challenged and modified by feedback from these consultants. The seating would be used by the students themselves and their peers. Thus the developers were themselves key stakeholders.

2. As the unit unfolded, new aspects were added to the brief. For example, when the students had decided on the taniwha shape, they needed to list attributes for the necessary materials. By making the prototype of the whale, they learnt how to create a smooth, decorative surface, which then became a new attribute for the final seat. It was a good thing they weren't forced to stick to their original ideas!
3. The students had previously made papier mâché puppets, which were built around frames made from a variety of materials. This "hollow sculpture" process seemed like a good place to start, and the familiar method was then adapted to solve a new problem.
4. The materials the students planned to use presented weight and consistency issues that had to be resolved. By deconstructing familiar art processes, they came up with strategies for overcoming the problems. After this, they needed to make a prototype to see whether their ideas would work.

Useful References

The following resources explore, in other contexts, the key aspects of technological practice exemplified in this article.

Stakeholders and Consultants

- The New Zealand Curriculum Exemplars: *Technology* (Learning Media, 2003, or **www.tki.org.nz/r/assessment/exemplars/tech/index_e.php**)
  Level 5, Avocado Harvester
- Futureintech (**www.futureintech.org.nz**)
  "People talk about their jobs"
- IPENZ (**www.ipenz.org.nz/ipenz/careersed/neigheng/neawards.cfm**)
  The IPENZ site provides contact details for anyone wishing to access the Neighbourhood Engineers Scheme, an online case study of the Verran School taniwha project, which won the primary school category of the 2002 Neighbourhood Engineers Awards, and case studies of other past winners.

Brief Development and Planning

- The New Zealand Curriculum Exemplars: *Technology* (Learning Media, 2003, or **www.tki.org.nz/r/assessment/exemplars/tech/index_e.php**)
  Level 2, Library Environment
  Level 2, Kidzdough
  Level 5, Bug Off Bands
- Techlink (**www.techlink.org.nz**)
  "Career Profiles – Andrea Moore Design"

Making Use of Existing Knowledge

- The New Zealand Curriculum Exemplars: *Technology* (Learning Media, 2003, or **www.tki.org.nz/r/assessment/exemplars/tech/index_e.php**)
  Level 4, Plant Environments

Modelling and Prototyping

- The New Zealand Curriculum Exemplars: *Technology* (Learning Media, 2003, or **www.tki.org.nz/r/assessment/exemplars/tech/index_e.php**)
  Level 2, Library Environment
  Level 4, Plant Environments
  Level 5, Avocado Harvester
  Level 5, Wine Labeller

Further Activities

Enhancing Outdoor Environments

The following activity sequence will help your students to understand how the values, beliefs, and needs of both technologists and end-users affect the development of particular solutions.

The Main Features of the Suggested Learning Sequence

Brief Development

- The students identify an area in the school grounds that they would like to enhance with the addition of a plant container, a water feature, or some other feature made from hypertufa. (Hypertufa is a mixture of sand, peat, and cement that looks like natural rock when moulded.) The aim will be to make the area pleasant and restful for students and staff.
- They consider a range of focus questions that address important aspects of brief development. The questions should focus on the broad aims and scope of the project, environmental issues, health and safety issues, the stakeholders, socio-cultural factors, and consultation with stakeholders and outside experts.
- They work in groups, each of which writes a brief that defines a proposed outcome, the reasons for developing this outcome, and its key attributes.

Planning for Practice

- The students begin to develop the technical knowledge and skills they will need by visiting garden shops to appraise existing hypertufa (or hypertufa-like) products, by researching recipes for hypertufa and developing variations, by trying out different methods for moulding hypertufa, and by consulting with experts such as landscape gardeners and sculptors.
- They address a range of focus questions that explore the development of small-scale, 3-dimensional models. Each group makes a model of their proposed outcome and presents it to the stakeholders and outside experts for feedback.
- The class consider the feedback about each proposed model and select a single outcome to develop fully.
- They construct a detailed plan of action for developing this outcome, perhaps in the form of a Gantt chart.

Outcome Development

- As the students develop their outcome, they regularly reflect on their progress, annotating and adjusting the plan of action as appropriate.

Brief Development

The development of a brief requires us to consider a wide variety of issues, including our reason for developing the outcome, the outcome's environmental impact, the available facilities and materials, and the necessary skills and knowledge. Most importantly, the brief must take account of the people who will use or be affected by the outcome – that is, the stakeholders.

After realising that the Envirogroup had a problem, Room 5 began by setting one constraint: the conversation-friendly seating would have to seat at least twenty bottoms. This parameter allowed them to identify and discuss all sorts of possibilities before they had to narrow them down.

Visit the area with your students and decide, as a class, what sorts of outcomes would be useful. (The students may first need to find out what hypertufa is. The Internet is a great source of information.) Have the students consider a range of focus questions that address the broad aims of the project, environmental and safety issues, the stakeholders, appropriate consultation, and socio-cultural issues. (See the separate section of focus questions at the end of these notes.)

After the students have thought about the focus questions and found out what they need to know, ask them to work in groups and write a brief that states what they will be developing and why. They should also think about the key attributes they would like their proposed outcome to have, such as strength and aesthetic appeal. These attributes form the basis of the specifications of the brief.

What You Should Look For

- Have the students consulted widely enough to determine the relevant values, beliefs, and needs of the end-users and other stakeholders?
- Do their briefs adequately and realistically address these values, beliefs, and needs?

Planning for Practice

Developing Technical Skills and Knowledge

The students in the article used a variety of methods to model their intended outcome. They used their brief to guide the development of 2-dimensional plans, and 3-dimensional models helped them to identify features that would work well. The clay models also allowed them to focus on particular features rather than the outcome as a whole.

As part of their preparation for such a project, your students will need to learn how to manipulate and reinforce hypertufa. Making hypertufa is messy and hard on the hands, so make sure that the students select a suitable workspace and wear protective gloves.

The following activities will help the students to develop the technological knowledge necessary for their outcome.

- Visit a garden shop to study examples of hypertufa products whose attributes (and/or purpose) are similar to those of their intended outcome. After the students have identified such products, they should analyse them in terms of materials, structural components, aesthetics, and so on.
- Research online and in books to find recipes for hypertufa and techniques for working with it.
- Test hypertufa recipes to see which of them best suits the specifications.
- Here are some sample recipes to get them started if Internet access is not possible.
  Basic 1 part cement, 1 part sand, 2 parts peat
  Variation 1 1 part cement, 1.5 parts sand, 1.5 parts peat
  Variation 2 1 part cement, 1 part vermiculite, 2 parts peat
  Variation 3 1 part cement, 1 part sand, 1 part peat
- Experiment with the addition of various ingredients to change the appearance of the hypertufa.
- Experiment with various moulds or other structures to shape the hypertufa. Cardboard boxes or plastic containers make good bases for moulds, but they need to be strong and be lined with tough plastic so that the hypertufa will come free when dry.
- Consult with an expert, such as a landscape architect or a sculptor, to learn how to make their outcome strong and attractive.
- Locate appropriate materials for enhancing their outcome, for example, shells, pumice, broken pottery, and mosaic tiles.

Developing Models

When the students have completed their research, have them consider a range of focus questions to help them plan how to develop models of their intended outcomes. (See the separate section of focus questions at the end of these notes.) The students can then proceed to make the models and to seek feedback on them from stakeholders and consultants.

What You Should Look For

- Do the students' models reflect knowledge of the physical properties of hypertufa and techniques for its manipulation?
- Do the models reflect previously identified stakeholder values, beliefs, and needs?

Selecting a Final Outcome to Develop

After the students at Verran School had presented their models to the stakeholders and consultants, they selected the best outcome and planned how they would make it. They reflected on what they had learnt from their consultants, previous experiences, and exploratory activities. Then they modified their ideas accordingly.

At this stage, your students should consider focus questions that address the stakeholder feedback about their models and select one outcome to develop. (This may be based on a combination of features from several of the models.) They should then consider a range of focus questions on the steps for developing the final outcome and the associated time and resources. (See the separate section of focus questions at the end of these notes.)

The following activities will help your students plan how to develop the final outcome that they have selected.

- Make a flow chart that shows the general steps involved in the process of making a hypertufa product. Add extra steps to reflect specific details of the selected outcome.
- Discuss the various stages and produce a Gantt chart to show how long each stage is expected to take and which stages need to be completed consecutively or concurrently.
- Contact the consultants again to make sure they will be available for support at critical times.

What You Should Look For

- Do the students' plans reflect their knowledge about materials and processes? Have they allowed sufficient time for each step, and are those steps organised in a logical and time-efficient sequence?
- Do their plans reflect their own experiences and the ideas they have gained from other people's technological practice?

Outcome Development

It may be helpful to record the chosen hypertufa recipe on a large sheet so that the whole class is able to refer to it. It may also be useful to refer to the Gantt chart at the beginning of each session and reflect on progress. As the students construct their outcome, they should regularly and critically reflect on both the brief and the progress through their plan. The brief and plan will undoubtedly need to be adjusted more than once in response to this ongoing evaluation. (You may wish to include enough space on the Gantt chart for the students to write on as they go. This will allow them to record their original plan, all the modifications to it, and the justifications for those modifications. These records will be useful for future analysis and reflection.)

What You Should Look For

- Do the students effectively evaluate their outcome against the specifications in the brief?
- Have their plans proven flexible enough to accommodate unanticipated results and events?
- Have their plans proven flexible enough to allow the specifications in the brief to be refined?
- Have the specifications proven to be solid evaluative criteria?

Focus Questions – Brief Development

Broad Focus

What is the issue or need we are trying to address?
Where will our solution be situated?
Where will it be developed?
What facilities and materials will be available for us to use?
Do we have a budget?
What is it?
What can we do to get extra funding if we need it?

Environmental and Safety Issues

What impact will the structure have on the environment?
Will the structure be safe for everyone to use?
How will we know what "safe" is?
Are there any regulations about this?
How can we find out?

Stakeholders

Who will be using or benefiting from the structure?
Who else will be affected by the structure (for example, the caretaker, principal, duty teachers)?
What do the stakeholders think about the area as it is?
What do the stakeholders think about our ideas for enhancing the area?
How will we find this out?

Consultation

What will we need to do in order to turn our plans into a reality?
What sort of help will we need to complete our structure?
Who might provide this help (for example, a builder or plumber)?
How can we find out which community organisations and individuals might be able to offer advice?
How can we get these people interested and excited about what we're trying to do?
At what stage(s) of the process should we seek specific advice from consultants?
Are there any building regulations that we need to be aware of?
How will we find this out?

Socio-cultural Factors

Are there any cultural factors that might affect the design and use of the structure?
Is it important to reflect the stakeholders' culture(s) in the outcome?
Who should we discuss this with?

Focus Questions – Planning for Practice

Recapping New Knowledge

What useful things have we learnt from our research activities?
What useful things have we learnt from our consultants?
How can we develop models to test particular design ideas?

Stakeholders

Who will see our models?
How will we find out what they think?

Resources for the Models

What materials will we use for the models?
Where will these materials come from?

Analysis of Feedback on the Models

What are the implications of the feedback that our stakeholders gave us?
How will the class as a whole select the best idea to develop further?
Which of the models' features should we include in the final outcome and why?

Planning the Final Outcome

What steps will be involved in developing the outcome?
Do we need to develop mock ups or prototypes, or can we proceed directly to develop the outcome?
Which parts of the process can we complete independently, and which will we need help with?
How will our consultants be able to help us?
When will they need to be available?
How are we going to make sure they will be available?

Resources for the Final Outcome

What materials are we going to need?
Where will these come from?
How will we get them?
How can we manage the materials to save money and minimise environmental impact during the construction?

Pond Puzzler

Possible Achievement Objectives

Mathematics

Mathematical Processes

- Devise and use problem-solving strategies to explore situations mathematically (Problem Solving, all levels);
- Use equipment appropriately when exploring mathematical ideas (Problem Solving, all levels);
- Record, in an organised way, and talk about the results of mathematical exploration (Communicating Mathematical Ideas, levels 2–3).

Developing the Ideas

This deceptively simple game can be played and explored at various levels of complexity, beginning with the 7-lily-pad version in the scenario. It can be given to students as a game to try at home with their parents, as a group activity, or as a whole class activity with opportunity for play in pairs. However it is introduced, it will only take students a few games before they are certain that the person who starts has an advantage. The challenge then is to find and describe the winning strategy, try and explain why this strategy works, and then see whether the same strategy holds for an increased number of lily pads.

The game can provide an excellent experience in problem solving, with opportunities for:

- devising, using, and modifying problem-solving strategies;
- seeking solutions through trial and improvement;
- choosing and using suitable equipment;
- “acting it out”;
- investigating alternatives;
- looking for patterns, using diagrams to explore their structure;
- falling back to simpler cases;
- recording results systematically.

You may find that most students want to play the game using equipment. Circles drawn on paper will do for lily pads, and while a set of cheap plastic frogs would be ideal, counters or any other kind of markers will do just as well. If you are using equipment, the frogs or counters should ideally all be the same colour. This will help make the important point that while alternate players place them, once on the lily pad, they are not “owned” by either.

There are four phases to this activity:

Phase 1: Clarify rules, organise equipment, and clarify the object.

During this phase, you should make sure that everyone understands the rules of the game, that they have whatever equipment they need, and that they understand that they are looking to show that Freda is either right or wrong in her belief that she can always win. Ask your students what they think is meant by Freda “playing as cleverly as she can”.

Phase 2: Play the game with 7 lily pads, look for patterns, and describe a winning strategy.

This is best done in pairs, and the students should be allowed to keep playing until they can see what is happening and are able to report back to the class. If you prefer groups of four, insist that all members of the group take turns at playing. Key questions could be:

- Can Freda always win? Why, or why not? (Yes, she can – but only if she is allowed to go first every time! Going first allows her to control the game.)
- Is there a best place to start? (Yes, the middle lily pad)
- How many moves does a game have? (The minimum is 3, because you need to get 3 frogs in a row to win. The maximum – and usual – number is 5: frog number 4 must end up next to another frog, so the next player will place frog number 5 next to those two to make 3 in a row.)
- What difference does it make where Bull places his frog? (The only difference is whether the game is over in 3 moves or 5.)
- How soon can you tell who the winner will be? (As soon as it is decided who will start.)
- What is the strategy that enables Freda to win every time? The strategy that the students describe must cover all possible moves, subject to Freda playing as cleverly as she can. (She should put the first frog on the centre lily pad, then wherever Bull puts his, she should put hers on the “mirror” lily pad on the opposite side of the centre.)

Phase 3: Extend the game, record sequences, and make and test a generalisation.

Your students should now extend the row of lily pads to 9, and then to even greater odd numbers. As the number of pads increases, a game will have more moves, so the students need to devise a system for recording their moves for further analysis. One strategy is to use a grid like the following one, where each line represents a row of lily pads. (You may find it useful to run off recording grids for your students.) Numbers can be used to represent the order in which the frogs are placed. If Freda has the first move, all her placements will be odd-numbered, and Bull’s will be even-numbered. The number of lily pads “in play” can be shown by blacking out all the unwanted squares on that line. Here are two possible games, the first using 11 lily pads and the second using 13:

	3				1		4	5	2									
4		6	2	7		1			3			5						

Encourage the students to play quite a few games, swapping the Freda and Bull roles from time to time and gradually increasing the number of lily pads, always to an odd number. Expect them to discuss their conclusions in their pairs or small groups and to report back. They should be able to conclude that:

- Using any odd number of lily pads, Freda can always win if she plays as cleverly as she can.

- Playing cleverly, she should put her first frog on the middle lily pad and then match Bull's moves by placing a frog exactly opposite wherever he places his until she can make 3 in a row. (In other words, her moves are symmetrical to his about the centre.)
- Trying to avoid giving Freda 3 in a row, Bull needs to make sure that he places his frog so that there are at least 2 empty lily pads between it and the next. But if he can find a safe move, so can Freda – on the other side of the centre. So he will always run out of safe moves before Freda does.
- If Freda wins, there is an odd number of moves in the game.

Phase 4: Further extend the game, record sequences, and modify the generalisation.

Your students should now try even numbers of lily pads, starting with 8. They will realise that now there is no centre lily pad, so the symmetry strategy that was successful before doesn't quite work. They are likely to discover, however, that if Freda starts in one of the two middle squares, she will win all the time when playing with 8 or 10 lily pads, but when they're using 12 lily pads, Bull can win every time.

Extension: Challenge your able students to show why this is the case.

The key to understanding and demonstrating this is the concept of "safe distance" between occupied lily pads. If there are 2–4 empty pads between frogs, no other frog can be placed in that gap without allowing the other player to complete 3 in a row and win. This concept is illustrated by the following diagram. The frogs (shown as Xs) are all a safe distance from each other – but no frogs can be placed on the shaded lily pads without giving away the game.

x			x				x					x

Once the students understand this concept, they have a strategy for analysing any number of lily pads. They can work out how many safe moves are possible; if this number is odd, Freda wins; if even, Bull wins; if both are possible, either can win.

Example 1: Playing on a row of 8 lily pads, there are only 3 safe moves (an odd number), so Freda must win. Here are the two possibilities:

Either		x			x			x	(odd)
or	x				x			x	(odd)

Example 2: Playing on 12 lily pads, there are either 3 (odd) or 4 (even) safe moves, so either Freda or Bull can win. This diagram shows how:

Either			x			x			x			x	(even)
or		x				x				x			(odd)
or	x					x					x		(odd)

But Bull can always win as long as he places his first frog so that there are 5 lily pads between it and Freda's frog. By doing this, no matter where Freda places her first frog, Bull can ensure that there will be an even number of moves in the game, which means he will win. The chart shows the possible arrangements after Freda and Bull have placed their first frogs. (It doesn't matter which is which.) The unshaded squares are the only safe places left.

Either	x						x						(even)
or		x						x					(even)
or			x						x				(even)
or				x						x			(even)
or					x						x		(even)
or						x						x	(even)

Further Activities

Those who have got this far could investigate what happens with 14 lily pads. They should find that the strategy of choosing a centre square and then mirroring the other player's moves will always work. (If they can't exactly mirror, the important thing is to allow for the same number of moves on each side of the "centre" frog.) They could think about why the mirroring strategy fails for 12 lily pads. (Only one side of the "centre" has 6 lily pads, the minimum needed if 2 frogs are to be "safely" placed.)

Your students may also like to explore the possibilities for a 4-in-a-row version of this game:

- Does such a game work?
- If so, what minimum number of lily pads does there need to be to ensure that both players have a chance of winning?
- What happens to the game as the number of lily pads is increased?
- How is the behaviour of the 4-in-a-row game different from that of the 3-in-a-row game?

Sticking with It

Possible Achievement Objectives

Science

Material World

- 2.2: Investigate and communicate differences in the properties of similar types of materials.
- 3.2: Investigate and describe how the physical properties of materials are related to their use.
- 3.3: Investigate and report on temporary and more permanent changes that familiar materials undergo.

Nature of Science

- 2.3: Investigate the way common items of technology have developed.
- 3.2: Investigate examples of simple technological devices and link these with some scientific ideas.

The Specific Learning Intentions

The students will be able to:

- develop criteria for evaluating the effectiveness of glues;
- plan and carry out an investigation to find the best glue for a particular purpose.

The Key Ideas

- Sticky substances occur naturally in nature.
- Some substances turn into glue when they are mixed with other substances and/or heated.
- The properties of a glue can be altered if the ingredients are changed.
- Particular glues are more effective in some circumstances than others.

Developing the Ideas

The suggested learning sequence focuses on developing students' investigative skills within the context of deciding which glue to use. The investigation could be carried out to meet needs identified in other curriculum areas such as the visual arts or technology. The context lends itself to different levels of investigation, from a simple "let's try it and see" approach to carefully structured fair testing.

Students often use the term "best" without defining what this means. An important part of the learning sequence is developing a set of criteria against which to judge various glues. Those criteria become the basis for deciding which type of glue is best for specific purposes.

Introductory Activities

- You could begin by leading an initial discussion about saps, some of which are sticky. Students could feel the sap from a newly cut piece of pine or gum tree or from a non-woody species, such as a daffodil or dandelion. Ask if they know of any other plants that produce a sticky substance. (**Safety warning: If using plants other than those suggested here, make sure that they are not poisonous or commonly allergenic. In all instances, have the students wash their hands afterwards.**)
- Have the class read "Sticking with It".
- On a chart, list the various sticky substances mentioned in the article and establish what they can be used for. In a class discussion, explore the ideas that:
    - the glues were used for a variety of purposes;
    - other materials could be added to improve the glues, for example, by making them stronger, easier to spread, or longer lasting, or to make them suitable for other purposes;
    - people in different parts of the world make glues from different materials, depending on what is available in their environment.
- Alternatively, you may wish to establish a Living World focus within which to investigate stickiness in nature. In that case, you could initiate the learning sequence by asking the students to:
    - think of or find examples of sticky substances in nature and suggest reasons why they are sticky;
    - suggest ways in which people might use the substance or copy "nature's idea".
- Remove the text from a number of fields in the following table and challenge the students to fill in the gaps by accessing a variety of information sources.

Substance or structure	**Main sticky ingredient(s)**	**Purpose in nature**	**How used or copied by people to make sticky substances**
Resins	Thick, flammable oils	To protect the plant, for example, by discouraging browsers and by sealing wounds	Traditionally used by Pasifika peoples for a variety of purposes
Fruits	Pectin (a gelatinous polysaccharide [sugar])	To encourage animals to eat seed-bearing fruits and so disperse the seeds	Used as a setting agent in jams and jellies

Grains and tubers	Starch (a polysaccharide present in many human food staples)	To provide energy to germinating plants	Wheat flour used as the base ingredient for adhesive paste
Gristle, bones, and hooves	Collagen (a protein)	To strengthen tissues, including connective structures	Boiled up and used for making glue

Further Activities

Investigation: Deciding Which Is the "Best" Glue

What You Need

- A selection of glues or sticky substances, such as Moo Glue, flour paste, glues from the school storeroom, sticky tape, and natural sticky products such as gum from a tree or other natural products containing sugar, such as golden syrup and honey
- A variety of materials for sticking, such as papers, fabrics, cardboard, wood, string, leaves, and beads

What You Do

- Pose the question "Which of these glues is the best?"
- Ask the students to help you to draw up a set of criteria to define "best". This could relate to a particular purpose, such as a collage picture. The criteria might include:
  - is strong enough to attach light/medium-weight/heavy objects to an upright piece of cardboard;
  - is not visible;
  - holds fast when dry;
  - does not discolour;
  - does not go mouldy;
  - does not attract ants;
  - is easy to apply.
- Ask the students to plan an investigation. It could be a fair test or another type of investigation. (The students may be more familiar with fair testing than with other types of investigation. You could begin by discussing the various types of investigation described on page 11 of the Ministry of Education's *Making Better Sense of the Living World* (Learning Media, 2001).
- The investigation could be organised in one of the following ways, depending on the students' previous experience with investigating and the available time.
  - whole-class investigation into all the sticky substances;
  - small-group investigations in which each group tests one sticky substance and then combines their results with those of the other groups;
  - small-group investigations in which each group tests all the sticky substances;
  - whole-class or small-group fair testing investigation (The tests must be identical, except for the type of glue used. For example, each test should use the same amount of glue and the same type and size of samples for sticking. The tests should all be carried out on the same day in the same area so that the atmospheric temperature and humidity are consistent.)
- At the end of the investigation, the class should consider all the results against the set of criteria and reach a consensus about which sticky substance is the best glue (for a particular purpose if stipulated).

What You Look For

- Can the students develop suitable criteria for an effective glue?
- Do they accurately follow their plan when carrying out their investigation?
- Do they adapt their plan appropriately if it does not work? Can they describe and justify any such adaptations?
- Are they able to use appropriate data from their investigation to justify their conclusion about which glue is best?
- Do they demonstrate awareness that different glues may be best for different purposes?

Discussion Activity: Deconstructing a Glue

Another focus for investigation could be the properties of the substances that make up a glue. You could gather the ingredients for Moo Glue, flour paste, or another easily concocted glue. Ask the students to describe the properties of each ingredient. Have them make up the recipe and compare the properties of the final product with those of the original ingredients. Identify the actions that changed the properties of each ingredient.

Activities from Other Ministry of Education Publications

Making Better Sense of the Material World (Learning Media, 1998) includes a recipe for casein glue on page 55. Pages 64–67 explore the science behind substances that "harden, slime, and ooze".

- *Sand, Salt, and Jelly Crystals*, Book 16 in the Ministry of Education's Building Science Concepts series (Learning Media, 2001), includes an activity that could be adapted to focus on the properties of glue ingredients. See page 8, Activity 2: Checking Children's Observation Skills.
- The New Zealand Curriculum Exemplars: *Science* (Learning Media, 2003, or **www.tki.org.nz/r/assessment/exemplars/sci/index_e.php**) Level 2, What a Mix Up
  This exemplar profiles a teacher giving feedback to a student who is drawing conclusions about her investigation of mixtures.
- TKI provides a short Level 3/4 unit called "Sticky Things" (**www.tki.org.nz/r/science/scienceschool/resources/1999/sticky2.htm**). The three activities explore the concept of stickiness with reference to a number of household materials and foods.

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