MINISTRY OF EDUCATION
Te Tāhuhu o te Mātauranga

Notes for Teachers

Connected 3 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 3 is designed to appeal to years 5–8 students working at levels 2–4. The series aims to reflect students' interests and experiences, expand their knowledge and understanding, and engage their imaginations.

General Themes in *Connected 3 2005*

The main themes in *Connected 3 2005* are the long-term storage of biodegradable materials, the physical and chemical properties of paper, the science of colour, and the mathematics of musical beat and rhythm.

1. Innovative Storage Solutions for Fresh Produce

"Our Pātaka" explores how a group of technology students developed a storehouse for the fresh vegetables they grow for their food technology programme. The most important specification for their storage structure was that the internal temperature should remain as stable as possible. Their final outcome was a pātaka-like building that had grass turf on the roof. This unusual design minimises temperature fluctuations because the water that evaporates from the turf or transpires from the leaves during the day carries heat away and stops the building heating up inside. At night, the evaporation drops markedly, and so the building doesn't continue to cool down overnight.

The teachers' notes for this article suggest ways of guiding your students through a unit in which they develop a customised storage solution for their own home.

2. Plant Fibres, Paper, and Appropriate Storage

"Te Aute" explores how early Māori brought the Pasifika bark paper tradition to New Zealand. They imported the aute tree and, from its bark, they continued to make the papery cloth we know as tapa, siapo, or ngatu. However, early European explorers recorded only occasional, small items of bark paper cloth in New Zealand. A possible explanation is that the tradition died out here because Māori found many indigenous sources of plant fibre that were far more abundant than the aute tree, which grows poorly in southerly latitudes.

"Rescuing Paper" focuses on another aspect of Māori papermaking – this time newspapers. In the mid-nineteenth century, a number of Māori-language newspapers appeared in print. Surviving copies of these historic documents are housed in various collections around New Zealand. Because newsprint is paper of relatively low quality, archivists and conservators face many challenges in repairing and storing valuable old newspapers.

The teachers' notes for these items focus on the ageing of paper. In the suggested investigation, students develop a colour scale to help them to objectively judge the degree to which newspaper samples have yellowed. They then design an investigation into the speed at which newspapers deteriorate in different storage conditions. Their yellowing scale helps them to make objective judgments when gathering their data. At the end of the investigation, they consider when it's appropriate to use newsprint paper for particular purposes and when it's appropriate to use paper with different properties. The appropriate use of different types of paper is explored further in the notes for "Paper Colourscapes".

3. *Paper and Colour*

The chromatography activity in "Paper Colourscapes" relies on highly absorbent paper. Having explored what happens when you mix various primary and secondary colours, the students carry out an investigation into the best type of paper to use for chromatography. Afterwards, they analyse appropriate papers and inks for artworks and messages to go in a time capsule.

4. *The Mathematics of Musical Beat and Rhythm*

"The Right Beat" explores both the relative time values of semibreves, minims, crotchets, and quavers and the way in which a composer's or performer's choice of beat, tempo, and rhythm can influence the mood of a piece of music. The teachers' notes suggest classroom activities through which students can explore the mathematics of beat and rhythm by performing the same song in different ways. There is potential for peer tuition in this context if you identify the students in your class who have experience in studying, writing, or performing music.

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Our Pātaka

Possible Technological Areas

Biotechnology
Structures and Mechanisms
Materials Technology
(See the Specific Learning Intentions for links to relevant achievement objectives.)

The Specific Learning Intentions

The students will be able to:

- develop a brief that includes appropriate product attributes and specifications and use this brief to guide the development of their outcome(s) (AO 1, 2a, 3, 4, 5, 6a, 7, 8);
- locate appropriate information and use it effectively in developing the brief and planning how to implement it (AO 6a–b, 7, 8);
- develop conceptual drawings, mock-ups, and models in order to test and refine their ideas before creating their final outcome (AO 4, 6c–d).

The Key Ideas

The following aspects of technological practice are exemplified in "Our Pātaka". The students could use this case study to guide their own practice in a wide range of contexts and activities.

Brief Development: The students' early identification of key attributes should support their later technological practice. As they learn more and develop their ideas, they can refine the initial attributes and develop specifications against which their ideas, models, and final outcome can be evaluated.

Knowledge Building: The students' understanding of science ideas – and their creative application of this knowledge – is often crucial to an outcome's success. (Other knowledge bases from which technologists often draw include social studies, mathematics, the arts, and economics.)

Planning for Practice: The students' brief and plan of action should provide enough structure to ensure that everyone knows what they need to do and what resources they will need to organise. At the same time, the brief and plan of action should be flexible enough to allow refinements as the students develop new ideas and come up with solutions to unforeseen problems.

The Main Features of the Suggested Learning Sequence

- The class discusses the key aspects of technological practice that "Our Pātaka" exemplifies.
- You and the students identify a home storage issue that they wish to address. (The issue might be the storage of fresh produce, or the students may wish to address another storage issue, in which case, you will need to modify and/or extend the suggested activities as appropriate.)
- The students explore other people's brief development in different contexts by reading selected Ministry of Education technology exemplars. In this way, they can decontextualise the technological practice described in "Our Pātaka", identifying and discussing generic technological principles and practices.
- In order to define their home storage issue more specifically, the students take home a set of focus questions to discuss with family members.
- They research how other people have resolved similar storage issues in historical and contemporary contexts.

- They use the information gathered from their research to develop an initial brief that broadly defines what they wish to achieve and includes a set of key outcome attributes.
- Having discussed their draft brief with you and their peers, amending it as appropriate, they develop a list of specifications that are based on the already-identified attributes.
- They develop specific plans and diagrams for their storage solution, generate a list of required materials, and develop a time-based plan of action for testing and refining their possible solution.
- They carry out this plan. As they develop their outcome, they evaluate it against the brief on an ongoing basis through self-, peer-, and teacher-review processes.

Developing the Ideas

In order to focus the students' minds on the important aspects of technological practice exemplified in "Our Pātaka", you could discuss the following key ideas in the storyline.

Brief Development

Once the students had identified the need for long-term vegetable storage in the school, they talked to their teacher and brainstormed key attributes for a school storage facility. From these attributes, they developed a set of draft specifications and possible solutions. They shared their provisional thinking with the food processing engineer, who gave them more ideas, based on storage technology in local industry.

- They learnt about the factors that contribute to successful, long-term storage. They used this knowledge to refine the list of draft attributes and specifications.
  - For example, they discovered that daily temperature fluctuation is the main problem when you store the vegetables in question. The engineer guided them as they identified product specifications that would achieve an even temperature.
  - Other factors hasten deterioration, too, including bruising or dampness. The students therefore developed specifications that would mitigate these factors.
- In the brief development process, they also considered the stakeholders and the environment, both physical and social.
- Having considered the issues, the students wrote a class brief for their intended outcome. The attributes provided starting points for the specifications in the brief. These specifications were used later to evaluate the success of the outcome.

Knowledge Building

Because the structure would have to work without ongoing energy inputs, a heater and air conditioner were out of the question. The students needed to reflect on their past experiences to come up with innovative strategies for maintaining an even temperature inside.

- With a little prompting, they recalled that perspiration cools the body. The class brainstormed ideas that would mimic this phenomenon on a building rather than a body.
- To make the building "sweat" during the day, it needed a certain amount of direct sunlight, but not so much that it would heat up. Suitable placement was therefore an important consideration.
- The great thing about the turf-roof solution was that the building would not continue to "sweat" in the evening. Because of this, it would not chill down too much overnight.

Also, the students researched storage structures that other people have developed.

- During this research, a student found a book that showed traditional Māori storehouses, which are called pātaka.
- The class discussed the structural features that make pātaka effective, and they agreed that they should pursue a solution that was broadly based on those features.

Planning for Practice

Once the students had decided on the evaporation strategy and the basic pātaka structure, they were ready to develop ideas for possible solutions. Working in groups, they revisited the draft attributes and specifications that they'd already developed.

- Attributes such as "user friendly", "strong and durable", and "vermin proof" had to be carefully defined and deliberately planned for.
- Each group's plans were presented to the class, and the best ideas were chosen. These ideas needed to be clearly recorded so that the expert consultants could interpret and comment on them.

The local farmer offered to draft their plans to a professional standard so that they could be taken to a builder for advice.

- The students developed conceptual drafts of potential outcomes to guide their further thinking. The farmer developed these plans to a professional standard, and the students used them as reference documents for the consultants from whom they were seeking advice.
- At this point, they discovered that their ideas were going to be too expensive. So, although they retained most of the general features of a pātaka, they had to modify the proposed roof design. In doing so, they avoided hiring a structural engineer, and their innovative turf solution remained affordable.
- Their final plans were detailed enough to allow them to identify the materials they would need, to calculate the associated costs, and to ensure that resources would be available when they were needed.

Further Activity – Developing Home Storage Solutions

Once the class have read "Our Pātaka" and discussed some of the key aspects of technological practice that the article exemplifies, you could introduce the issue of storing fruit and vegetables at home. (Depending on your students' interests and experiences, the suggested learning sequence that follows could be adapted to address the long- or short-term storage of other foods or of non-food perishables in a variety of situations.)

The Issue: "We've seen how a school addressed the problem of storing garden produce. It's often a challenge to store fruit and vegetables successfully at home, too. We're going to investigate ways of prolonging the shelf life of fresh produce and develop long-term, non-refrigeration strategies for the home."

To support this project, you may wish to access the Neighbourhood Engineer Programme, which links students with a local technologist who has the skills and knowledge they will need for their identified project. The service is free, and the programme includes an annual award, so your students may even win a prize!
www.ipenz.org.nz/ipenz/careersed/neigheng/neawards.cfm

Brief Development

Brief Development – Case Studies

In order to investigate brief development in contexts other than storage (in other words, to decontextualise and therefore generalise key technological principles and practice), the students could explore relevant exemplars, for example, Library Environment or Courtyard Crisis. (See *The New Zealand Curriculum Exemplars: Technology* [Learning Media, 2003 or **www.tki.org.nz/r/assessment/exemplars/tech/index_e.php**].)

In Library Environment, students developed cushions for their school library. Before they began work, they carefully considered the physical and social environment and identified the key stakeholders. You could lead a discussion about the brief development process in this exemplar and have your students make a chart that identifies how Dexter's class went about it. For example, they:

- identified the need for an improved library environment;
- identified the physical and social features of the library and the physical and social needs of the people using it;

- decided to focus on cushions as a possible enhancement for the library environment;
- developed lists of appropriate attributes for this proposed outcome;
- identified the resources necessary to make cushions with those attributes.

Later in the activity, the students could make a parallel chart with similar processes to help guide the development of a brief for their own storage outcome.

Brief Development – Focus Questions

To help define the need, the students could take home a list of focus questions and discuss them with family members.

- Which fruits and vegetables are stored at home outside the fridge?
- Where are they stored at present?
- Why are they stored there?
- How are the conditions there? (Think about temperature, light levels, moisture, air circulation, and so on.)
- Are these the best conditions for those fruits and vegetables?
- Do some fruits and vegetables last longer than others out of the fridge?
- What happens if the fruits and vegetables aren't stored properly?
- Are all fruits and vegetables best stored in the same conditions, or is it better to store certain types in different conditions?
- Are there some fruits and vegetables that shouldn't be stored together? (For example, it's sometimes said that onions and potatoes should be stored apart because the onions will make the potatoes rot.)
- Are the fruits and vegetables at home stored in containers?
    - What shape are the containers?
    - What are they made from?
    - Are they designed specifically for storing fruits and vegetables or are they for general food storage?
    - What storage conditions do our particular fruits and vegetables require?
    - Do our present containers provide those conditions?
- How could we improve the current storage containers or areas?
- If we were to design a customised fruit and vegetable container, where would it go in our house?
    - What are the main problem animals we'd need to keep out?
    - Are there areas around the house where fewer of these pests are likely to be?
    - Would those areas be suitable for our storage container and for the particular fruits and vegetables inside it?
- Are there any cultural food practices at home that we need to consider?
    - Are there any foods that shouldn't be stored together for cultural reasons?
    - Are there any areas where food shouldn't be stored?
    - Are there any materials that we shouldn't use?
    - Are there any container shapes or decorations that would be appropriate or inappropriate?
- How big should the container be?
- Would any materials not be suitable for our specific contents or location?
- Should we develop a portable container? If so, how heavy should it be when empty and full?

Brief Development – Research Activities

To inform the development of their brief, the students will need to gather more information about the issue. Identifying and appraising other people's solutions, both historic and contemporary, would be a useful start-up strategy.

- The students could investigate how people of different times and cultures prevented food spoilage.
  - Besides keeping food in pātaka, how did Māori traditionally extend its storage life?
  - How have people in hot countries stored food in historic and modern times? Which foods did/do they store fresh, and which foods did/do they preserve in some way before storing them?
  - Does the storage or preservation alter the food significantly or does it remain essentially the same?
- The students could read the storage instructions for packaged foods such as potatoes or carrots.
  - What are the best storage conditions for these foods?
  - Do these conditions suit all fruits and vegetables, or are there better strategies for some types?
- The students could contact local vegetable growers or marketers to find out how they store various types of produce.
- They could visit a local hardware store to investigate storage containers. They could talk to salespeople to find out their views on which ones would be best for different foods.
- They could collect advertising material from the hardware store or other sources, such as newspapers, letter boxes, and the Internet. They could also bring in a selection of food containers from home and analyse their features.
  - What key features of the containers make them fit for their purpose?
  - Are they designed for a particular type of food or are they for general food storage?
  - How do they prolong the storage life of the food?
  - What sorts of materials are they made from? Are they hard or soft materials?
  - Would they work if they were made from other materials?
  - How do they stay closed? Do they have lids? If so, how are they attached?
  - Are there any other moving parts?
  - Do they have features that make it easy to carry or move them around?
  - How big are they? Why do they need to be this size?
  - Have the manufacturers tried to make them look good? If so, how?

What You Should Look For

In developing their research strategy and in appraising the results of this research, do the students take account of a wide range of factors that are pertinent to their specific situation? For example, they might need to consider:

- social conventions;
- cultural practices;
- technical possibilities and limitations;
- scientific knowledge to do with food spoilage and the organisms and storage conditions that promote or inhibit it.

Writing an Initial Brief

Having explored the issues in depth, the students will be ready to devise an initial brief. Generate either a class brief or group/individual briefs that explain what the students wish to develop as a home storage solution. This brief will need to be flexible so that it can be altered as the students gain more knowledge.

The students could begin by looking at the chart on page 4 of "Our Pātaka". They could construct a similar chart that reflects the knowledge they have gained from their previous research, especially their investigation of existing containers. They should then draft the brief, including a list of attributes to do with factors such as size, materials, user-friendliness, strength, aesthetics, and so on. These attributes will form the basis of the specifications in the final brief.

Before the students settle on a particular solution to develop, you will need to discuss the availability and cost of suitable materials, for example, corrugated plastic board, wax paper, tissue paper, cardboard, fabrics, foam, and clay. (The students will need to revisit the cost issue when they have a clear idea of what their intended outcome will be.)

What You Should Look For

- Can the students appraise ideas from other people's practice, adapting and importing them into their own work approach?
- When appraising other people's practice, do the students continually reflect back on the specifics of their own situation, including opportunities, limitations, available financial and material resources, and sources of expert advice within the local community and beyond?
- Can they identify the conditions in which their particular fruits and vegetables should be stored and link these conditions with appropriate attributes and specifications for their customised solution?

Planning for Practice

The students should now think about possible solutions that will fulfil the specifications of the brief, drawing labelled diagrams, generating a list of required materials and other resources for each outcome, and considering all the stages that will be necessary to complete it. They could record these in a suitable planning format, such as a bulleted plan of action or a Gantt chart. This process will help them to gain a clear sense of what's feasible in terms of cost-effectiveness, human resources, timing, and so on. They could also share their initial plans with the end-users at home and invite feedback.

What You Should Look For

- Do the students think creatively but realistically when coming up with possible solutions?
- Do they sensibly plan their allocation of time and resources once they've broadly defined what they're going to develop?

Outcome Development and Evaluation

Case Study

The students could read pages 4–6 of the Plant Environments exemplar, which show how Kendra's initial plans allowed her to test her ideas by making mock-ups. As she identified problems with her design, she mocked up various solutions.

Activity

In order to test and refine their ideas, the students could also use labelled diagrams and physical mock-ups made from paper, cardboard, or other suitable materials. Such models can be very helpful when you're perfecting a proposed outcome's size, shape, ergonomics, information labelling, and so on.

Mock-ups aren't necessarily complete. The students might find it useful to mock up only parts of the outcome to test, for example, how a lid or handle could be attached or how widely grips should be spaced.

Once the outcomes are finished, the students should complete the evaluation that's been ongoing throughout the unit by evaluating the outcome(s) against the specifications of the brief through teacher-, peer-, and self-review processes.

What You Should Look For

- Throughout the unit, have the students sensibly incorporated the results of their research, creative thinking exercises, planning, modelling, and consultation?
- Have they shown an ability to transform an idea from a mental concept to a tangible model for testing and evaluation (moving back to the conceptual stage and trying new ideas if necessary) and eventually to a final outcome? Throughout this development cycle, have they demonstrated open-mindedness, creativity, critical thinking and problem-solving skills, project management skills, and flexibility?
- Have they gathered sufficient stakeholder and expert feedback at appropriate times and through appropriate methods, for example, by developing diagrams and mock-ups that are sufficiently detailed to allow effective feedback?
- Have they adopted a flexible, non-linear approach? For example, on the basis of their ongoing evaluation, have they moved flexibly between the brief development, planning, and outcome development phases – revisiting stages and processes as necessary and updating the brief in the light of new knowledge and ideas?

"Te Aute" and "Rescuing Paper"

Possible Achievement Objectives

Science

Material World

- 4.2: Investigate and explain how uses of everyday materials are related to their physical and simple chemical properties.
- 4.3: Investigate and describe ways of producing permanent or temporary changes in some familiar materials.

Investigative Skills and Attitudes

- 3/4: Use appropriate instruments to enhance observation or to introduce quantification (Information Gathering).

Nature of Science

- 4.1: Plan and carry out a "fair test" and make decisions about whether the conclusions drawn from an investigation are soundly based.

The Specific Learning Intentions

The students will be able to:

- develop a scale for measuring and recording the degree to which newspapers have yellowed;
- plan and carry out an investigation into the conditions that promote or inhibit the yellowing of newsprint paper;
- use the results of their investigations to draw conclusions about when it's appropriate to use newsprint paper for particular purposes and when it's appropriate to use types of paper that have different properties.

The Key Ideas

- As paper ages, its physical and chemical properties change.
- We can observe evidence of some of the associated chemical changes. For example, the visible yellowing and increasing brittleness of a newspaper indicate that acidic breakdown is occurring within the paper.
- The conditions in which a particular type of paper is stored (and the nature of the paper itself) affect the rate at which chemical changes occur within it.

- Scientists devise measuring scales (based on specific criteria) for analysing physical phenomena. In this way, they can make, record, and unambiguously communicate their observations and associated judgments.

Developing the Ideas

The following notes focus on the yellowing of stored newspapers – a phenomenon that most students will have seen, even if they haven't paid much attention to it. In the suggested investigation, the students will develop a measuring scale for newspaper yellowing and use this scale for making and recording observations in a simple fair test, which they will also devise themselves.

Many students will be unaware that all measuring scales are human constructions. We use such scales on a daily basis for measuring, recording, and communicating many things, including temperature, length, speed, and time. These scales are so familiar to us that we usually accept them as givens without reflecting on where and how they originated. Many students will be surprised by the notion that these scales all began when a person or a group of people devised both a means of measuring the phenomenon and a scale with appropriate units for recording and communicating the data.

(This is an important Nature of Science topic, and the students might be interested to research the history of well-known examples such as the Richter scale and the modified Mercalli scale, both of which measure earthquake intensity in different ways. The Richter scale is based on the amount of energy released by an earthquake, whereas the modified Mercalli scale is based on the physical damage caused by an earthquake in a particular place – from 1 [very mild damage] to 12 [total destruction].)

Further Activity

The following activity will develop the students' awareness of the constructed nature of measurement scales. By devising a simple colour chart and using it to compare the degree to which samples of paper have deteriorated over time, the students will experience how the process of developing a universal scale helps everyone to make fair, independent judgements about their observations.

Investigation: How Yellow Is Yellow?

What You Need

- A selection of newspapers of various ages
- Paints or paint charts
- Paper

What You Do

- Before running the activity, collect old newspapers in varying stages of yellowing.
  - You may need to set up some samples well in advance. Several months before running the activity, begin to store newspapers in sunlight.
  - Start off a fresh sample every week and record the date so that you end up with a variety of yellowness and an indication of the speed of the changes.
  - Within a single newspaper, you can achieve a range of yellowness by layering and splaying the pages.
- Having prepared or collected the newspaper samples, ask the students to carefully observe their colours and to rank them from the least yellowed to the most yellowed. (They could also look at the dates if these are available. Does a clear pattern emerge from the dates?)
- Discuss the idea that scientists may begin the process of making a new measurement scale by carrying out careful observations like this. Once the range of the variable is known, scientists can begin to construct a set of units for recording gradations along that range.

- Help the students to use their observations to construct a “yellowing scale”. This scale will later be used as a benchmark against which test samples can be compared.
  - They could create this scale by mixing varying amounts of yellow, ochre, and/or brown paint with white.
  - Alternatively, they might be able to use colour charts from a paint shop. (Some students may suggest using the newspaper samples themselves, but these will not be stable. They will continue to yellow.)
- Once the students have constructed their scale, they could assign numbers to it so that the results of their comparisons can be recorded easily.
- The students will now be ready to design and carry out an investigation in which they store newspapers in different environments. The aim of the investigation is to explore the storage conditions that promote or inhibit the ageing of newspapers. Encourage the students to take the lead in devising an effective method. Help them with leading questions or open-ended, non-specific suggestions if they become stuck for ideas or ask you for help. They will need to take account of a number of factors in this planning phase.
  - Where will they place their newspaper samples to test a wide variety of conditions? For example, they might choose a window sill exposed to early-morning sunlight, a window sill exposed to mid-afternoon sunlight, a window sill that isn’t exposed to direct sunlight at all, a shady part of the room, a box made from translucent materials, a box made from opaque materials, and a cupboard.
  - What the are important variables in such an experiment? For example, light levels, temperature, and humidity could all affect the results.
  - How can they control these variables? In a classroom environment, it’s impossible to control these variables in such a way that you’re changing only one factor with each storage method. (For example, it’s difficult to keep a newspaper’s temperature the same when you change its exposure to sunlight.) For this reason, the investigation isn’t a true fair test. However, the students should still consider ways of controlling the variables as much as they can in order to make the test results as valid as possible.
- Newspapers yellow rapidly, but this is nonetheless a long-term investigation that could take a month or more. At the end of an agreed time, the students should use their colour scale to order the samples according to how much they have yellowed. They should then draw conclusions about the conditions in which newspapers yellow most quickly.
- As mentioned in “Rescuing Paper”, sunlight is a major contributor to the degradation of paper because the energy in light accelerates the chemical reactions involved. The students will probably identify sunlight as a key factor when analysing their results.
  - This inference is certainly reasonable, but ask the students whether they can be absolutely sure about it.
  - How might they design a further investigation to test this provisional conclusion about the importance of light levels? For example, they might suggest a second “fair-test-like” investigation in which they keep light levels and other conditions as even as possible while varying only the temperature or the humidity.
- Near the end of the unit, you should ask questions that reiterate the links between the students’ investigations and the context of artefact conservation in “Rescuing Paper”.
  - Why are some print publications made with newsprint while others are made with papers of higher quality?
  - Why is newsprint satisfactory for newspapers?
  - What other uses are newsprint and other types of paper suitable/unsuitable for and why? (This question could relate specifically to publishing or to a wider range of applications, including the use of various types of paper in artworks, cleaning products, storage products, baking products, and packaging.)

What You Should Look For

- Do the students understand the difference between subjective and objective judgments?
  - For example, can they explain why it’s more objective to relate their observations to a universal scale than to describe them in their own words?
  - Do they understand that all measuring scales are human constructs?

- When designing and carrying out their investigation, do they demonstrate understanding of the key principles of fair testing?
  - For example, do they identify important variables such as light levels, temperature, and humidity?
  - Do they suggest effective and realistic ways of controlling those variables as far as possible?
  - Given that certain variables are difficult to control, do they suggest effective and realistic ways of taking those potentially confounding factors into account? For example, do they suggest a second set of investigations that would effectively test their provisional conclusions?
- When identifying appropriate and inappropriate uses of various types of paper in various contexts, do they support their conclusions by referring to the specific properties of those papers? Do they understand that a property that's inappropriate in one context may be highly desirable in another?

Extension Activities

- The students could explore whether, as the paper's colour changes, other properties change as well, for example, brittleness. They could research and develop a brittleness scale.
- The students could investigate whether they get similar results if they test the factors that accelerate the ageing of other types of paper. For example, does photocopy paper or acid-free paper deteriorate more quickly in sunny, warm, or humid conditions?

Reference

Ministry of Education (rev. ed., 2001). *Making Better Sense of the Material World.* Wellington: Learning Media. (See especially pages 91–96, which provide background information for teachers and student activities that explore the physical properties of various types of paper.)

Paper Colourscapes

Possible Achievement Objectives

Science

Material World

- 3.2: Investigate and describe how the physical properties of materials are related to their use.
- 4.2: Investigate and explain how uses of everyday materials are related to their physical and simple chemical properties.

Nature of Science

- 3.2: Investigate examples of simple technological devices and link these with some scientific ideas.
- 4.1: Plan and carry out a "fair test" and make decisions about whether the conclusions drawn from an investigation are soundly based.

The Specific Learning Intentions

Students will be able to:

- identify mixtures of component colours that make up non-primary colours, for example, the blue and yellow pigments that are combined in green ink;
- demonstrate that some types of ink are more stable than others by investigating whether they separate into their component colours in chromatography trials;

- compare the physical properties of different types of paper;
- on the basis of their investigations, decide on the best types of ink and paper to use for particular purposes.

The Key Ideas

- What we see as a single colour may, in fact, be a mixture of two or more component colours.
- The colour mixture in an ink can sometimes be separated out if you use a particular solvent (for example, water, methylated spirits, or white spirits, depending on the type of ink) and allow the resulting solution to filter through a very absorbent paper.
- Artists, printers, and other people make reasoned decisions about the sorts of ink and paper they use according to their specific situation and needs.

Developing the Ideas

After the students have read "Paper Colourscapes", you could ask them whether they understand the terms "primary colour" and "secondary colour". (In terms of pigments, the primary colours are blue, red, and yellow.) If the students' knowledge is limited, they could experiment with blending different amounts of blue-, red-, and yellow-tinted water to create secondary colours. (Food colouring or watercolour paints could be used to tint the water for such activities.) For example, you could challenge them to create purple water, green water, orange water, and brown water.

Once the students have discussed and/or explored primary and secondary colours, they should try out the activity described in "Paper Colourscapes". Have them assemble a variety of pens (that have water-based inks) and ask them to predict which colours they think will separate out into different component colours. They should be able to predict at this stage that the primary-coloured inks are unlikely to separate out into different colours. (These inks may, however, separate out into different shades. For example, blue inks often separate out into turquoise and royal blue components.)

Inks are often made up of complex mixtures of pigments, and so the results obtained from non-primary-coloured pens may be surprising. For example, two brown pens may contain inks whose component colours are very different. Note that cheap pens may work best because their inks tend to separate into different colours very easily. More expensive pens may contain inks that are more stable. If blotting paper is unavailable, the students could try paper towels or coffee filter paper.

Further Activities

Investigation: How Does the Type of Paper I Use Affect the Behaviour of the Ink I Use?

This investigation links the ideas in "Paper Colourscapes" with those in "Rescuing Paper", which is also in *Connected 3 2005*. The investigation focuses on the absorbency of various papers. A paper's absorbency affects its suitability for chromatography experiments and for other specific purposes, such as artwork requiring a crisp, clear finish or artwork requiring a soft, slightly blurred finish.

What You Need

- A selection of different types of paper, for example, newsprint, paper towelling, photocopy paper, baking paper, soft cardboard, tissue paper, art paper of various types, and paper from a school exercise book
- Water tinted with food colouring
- Containers
- A selection of different coloured pens of various types, for example, felt-tips, ballpoints, and fountain pens

What You Do

- Ask the students to look carefully at the characteristics of each type of paper and record these details on a chart. (You could photocopy the example below, or the students could select appropriate adjectives from the text and create their own.) They should write ticks or crosses in the top six rows and make brief statements in the bottom two rows.

	Newsprint	**Paper towel**	**Photocopy paper**	**Water-colour art paper**	**School exercise book paper**	**Baking paper**	**Other**
Thick							
Soft							
Textured							
Embossed							
Shiny							
Smooth							
Absorbency: prediction							
Absorbency: actual							

- Ask the students to fill in all but the last row of the chart – by carefully observing the physical characteristics of the papers available to them and using these characteristics as the basis for their prediction about each paper's absorbency.
- Lead the students in a discussion of how they might design a fair test to investigate the absorbency of the different types of paper. (For an example of such a fair test, refer to page 96 of the Ministry of Education's *Making Better Sense of the Material World* [Learning Media, 2001]. If the students are stuck for ideas, you could mention one or two features of this model experiment to stimulate their thinking.) The students will need to consider:
  - how they will control the variables – for example, in the model experiment, the size and shape of the paper samples should be the same, as should the amount of each sample submerged in water;
  - what they will measure, for example, the time it takes the coloured water to travel a given distance or the distance it travels in a given time.
- As they carry out their investigation, they should record all the results and use the data to rank the papers in order of absorbency. They should complete the bottom row of the chart, comment on how close their predictions were to the actual results, and suggest explanations for unanticipated results.
- Encourage them to use the results of their investigation to select suitable papers for a particular artwork. For example, they could make a collage that incorporates a variety of papers and inks that create both crisp, clear, densely coloured effects and soft, blurred, washed-through effects.
- Ask students to evaluate their investigation. In their discussion, they should comment on whether they obtained the necessary information from their investigation and how they managed the variables. Encourage them to suggest improvements to their experimental design if necessary.

What You Should Look For

- Can the students use their observations of the physical characteristics of various papers as the basis for predicting how absorbent the papers are likely to be?
- Do the students use their experimental data effectively when planning their artwork? Does the students' artwork reflect their understanding of how both the different papers and the different inks behave?
- Can the students critique their investigations and suggest improvements if necessary?

Extension Activities

You could demonstrate the use of chromatography to explore the behaviour of waterproof inks when they're exposed to solvents such as methylated spirits or white spirits. Do these "colourfast" inks bleed and/or separate into component colours when exposed to particular solvents? (Note that methylated spirits and white spirits are classed as hazardous substances in the Ministry of Education's *Safety and Science: A Guidance Manual for New Zealand Schools* [rev ed., Learning Media, 2000]. Both these solvents release toxic fumes and are highly inflammable. Please refer to your school's health and safety in science policy and to the material safety data sheet (MSDS) for each substance before demonstrating its use.)

The students could carry out a long-term investigation into whether some types of ink are more fade-resistant than others. Do water-based or non-water-based inks last longer before fading? Are certain colours more fade-resistant than others? What effect do damp, heat, and sunlight have on the rates at which different inks fade? (For suggestions about similar student investigations, refer to the notes for "Te Aute" and "Rescuing Paper".)

Tying It All Together

Having thoroughly explored the behaviour of different types of ink and paper, the students could prepare messages and artworks for a time capsule. Ask them to choose the paper(s) and ink(s) they would use and to justify those choices. This could be a summative assessment activity.

References

The following publications include background information for teachers.

- Ministry of Education (rev. ed., 2001). *Making Better Sense of the Material World*. Wellington: Learning Media. Science Focus: Paper (pages 91–100) includes notes about the properties and production of paper and activities for exploring various papers.
- Ministry of Education (1999). *Making Better Sense of the Physical World*. Wellington: Learning Media. Pages 48–50 include background information about the visible colour spectrum and activities through which students can investigate the colours that make up white light.
- Ministry of Education (2001). *Seeing Colours* and *Light and Colour* (books 10 and 11 in the Building Science Concepts series). Wellington: Learning Media. Both books include detailed notes for teachers and suggested classroom activities. Sections 2 and 3 of *Seeing Colours* are particularly relevant. Section 4 of *Light and Colour* includes activities for exploring the colours of the spectrum.
- Ministry of Education (2004). *The New Zealand Curriculum Exemplars: Science*. Wellington: Learning Media. How Absorbing is a level 3–4 exemplar that would help your students to reflect on and critique their fair testing skills. See **www.tki.org.nz/r/assessment/exemplars/sci/material/mw_3c_e.php**

The Right Beat

Possible Achievement Objectives

Mathematics

Number

- Find fractions equivalent to one given (Exploring number, level 4).
- Express quantities as fractions or percentages of a whole (Exploring number, level 4).

Measurement

- Read and construct a variety of scales, timetables, and charts (Estimating and measuring, level 4).

Developing the Ideas

Sources of Information

This story explores the mathematical basis of beat and rhythm. Note that beat and rhythm are not the same thing. The beat is the underlying pulse, like a heartbeat – it can be fast or slow but is always regular. Rhythm is the pattern of long and short notes played over the top of the beat.

Note also that this story presents a situation designed to exploit the maths concepts that are inherent in music. In reality, composers would usually have a better feel for how their music was working, and musicians would solve any problems in a more intuitive way. Similarly, these notes suggest activities that draw out the maths of music, whereas learning in music normally takes a more organic approach that builds on students' practical musical experiences.

If you have a musical background, you should have little difficulty with the concepts underlying this story. If you don't, you may wish to or enlist the help of a musical colleague and consider a team teaching approach. If you have students in your class who learn music privately, make use of their knowledge. They may be able to explain musical ideas and to demonstrate them. An excellent introduction to all the musical ideas in this story, together with clear definitions of all the terms used, can be found at Neil V. Hawes' website. (Neil Hawes is a British musician and mathematician.) **http://ourworld.compuserve.com/homepages/Neil_Hawes/theory12.htm**

Introductory Activities

One way to introduce beat and rhythm would be to play a piece of pop or dance music. Play the selected piece once without comment or specific instructions. Then replay it a few times, posing questions or making comments to help the students focus on what they're listening to. For example, they could:

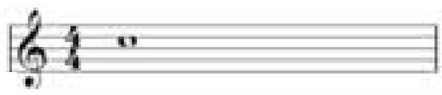
- clap or tap the beat, listening to the bass drum as a guide
- listen to the rhythms of the lyrics, keyboards, and guitar. (Are the voices and instruments singing or playing the same rhythm?)

Position a large clock at the front of the classroom. It must clearly show seconds, so use an analogue clock with a second hand or a large digital clock with a blinking colon. (Even better, if you have a metronome, set it to 60 beats per minute.)

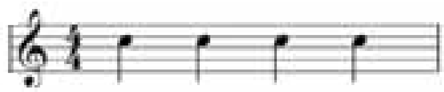
- Divide the class into four groups.
- Get one group to clap every second and explain that this group is clapping the beat.
- Once the beat has been established, get the next group to clap every two seconds.
- Bring in the third group, clapping every four seconds.
- Finally, bring in the fourth group, clapping every half-second.

You can now reintroduce the musical terms for notes of different lengths and establish the mathematical relationships between them. The students do not have to memorise the words but they need to be taught how to make sense of them.

- A semibreve (4-beat note) = 2 minims (2-beat notes); alternatively, 1 minim = $\frac{1}{2}$ semibreve.
- 1 minim = 2 crotchets (1-beat notes); alternatively, 1 crotchet = $\frac{1}{2}$ minim or $\frac{1}{4}$ semibreve.
- 1 crotchet = 2 quavers ($\frac{1}{2}$-beat notes); alternatively, 1 quaver = $\frac{1}{2}$ crotchet or $\frac{1}{4}$ minim or $\frac{1}{8}$ semibreve.
- Therefore, 1 semibreve = 2 minims or 4 crotchets or 8 quavers.

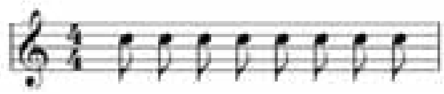


1 semibreve



4 crochets

2 minims



8 quavers

Explain that in the previous clapping activity, 1 crotchet beat = 1 second, so there were 60 crotchet beats in a minute.

- Now challenge the crotchet group to clap half as quickly (30 beats per minute).
- Bring the other groups in one at a time. Ask "Which group was tapping once per second?" (The quaver group.) Then ask the crotchet group to clap twice as quickly (120 beats per minute).
- "Which group was tapping once per second this time?" (The minim group.)
- This will help the students to realise that the lengths of the semibreves, minims, and quavers are relative to the speed of the crotchet beat.
- "So if the beat can be fast or slow, how might a musician know how quickly to play a piece of music?"
  - Often, a composer will specify a tempo (speed) at which to play the music, for example, ♩ = 100 beats per minute, or a word, usually in Italian, such as *allegro* (quickly) or *lento* (slowly).
  - In an orchestra, the conductor moves their baton in time with the beat so that everyone knows how fast to play.
  - The best tempo at which to play music can sometimes be influenced by the mood of the piece, by the lyrics, and by any dance moves that accompany it.
- Ask the crotchet group to tap a tempo of 120 beats per minute again.
  - Ask the semibreve group to sing the words of a very simple song in semibreves to this beat. ("Mary Had a Little Lamb" and "Twinkle, Twinkle, Little Star" work well. Your students may feel they are too old for these tunes, but if you acknowledge this, they may agree to sing them for the purposes of this activity.) "How does this sound?"
  - Then ask the minim group to sing it in minims to the same beat. "Does this sound a bit better?"
  - Have the crotchet group sing it in crotchets and then the quaver group sing it in quavers. "What happened to the length of time it took you to sing it?" "Have we altered the speed of the beat?"
  - Discuss why the first group sounded very slow and the last group very fast, even though the beat remained the same.
- To introduce the concept of bars, play the students a piece of (carefully selected) rap music.
  - You may find that it helps your students understand the principle underlying a bar if they think of it as a "container for notes". The number of notes that will fit in the container depends on the "size" (length) of the notes involved.

- A 4/4 bar will fit one semibreve, two minims, four crotchets, or eight quavers (or any combination of notes that add up to four crotchet beats). Get the students to listen to how the rapper makes use of notes of different lengths within each bar.

Encourage the students to see each bar as a unit, corresponding to 1 in mathematics. The total of the lengths of the notes and rests (non-notes or silences) must be the same for each bar. Those who have not been taught to read music may be surprised to discover that music has such a mathematical basis.

Now get the students to write their own chant. Give them a couple of lines of music manuscript with the bars marked off and ask them to write their chant, using just minims and crotchets. Some may have trouble thinking up their own words (or acceptable words), in which case, you could give them the lyrics from a poem. Here is an example:

You may find that this task works best if the students work in groups, each of which includes one student with some musical knowledge. Get them to perform their chants at a tempo of 120 crotchet beats per minute and time them.

Remind the students of the mathematical relationship between the kinds of notes (semibreve : minim : crotchet : quaver = 1:2:4:8), then get them to rewrite their chants using only crotchets and quavers. "Has the number of bars increased or decreased?" The students should time their rewritten chants (keeping the number of beats per minute the same) and compare the result with their time for the first version. By doing this, they should gain a practical understanding of the issues in the story and a sense for how "note value" contributes to the duration of a piece of music.

Further Activities

As an extension activity, you could give the students a manuscript for several bars of music (in 4/4 time) with complex rhythms. Have them assign mathematical fractions to the notes, checking that the notes in each bar add up to 1.

You could give them a simple piece of written music (in 4/4 time) and ask them to estimate the playing time. To begin with, they should assume that there is one crotchet beat per second. They can then get an accurate estimate by simply counting the number of bars and multiplying the result by 4. Then they could discuss the changes they would need to make so that the piece could be played in one-quarter of this time.

As a class, sing the final version of the song in the story. Some students could work out the melody on their instruments and teach the rest of the class to sing it.

Interested students could investigate the term "breve", using the Internet.

Links to the Number Framework

To make sense of the maths in this activity, students will need to be at stage 4 or beyond on the Number Framework.

Stage 5: Early Additive Part–Whole (Determining the notes needed to fill a given "time space")

The student is able to find a fraction of a number mentally, using addition fact knowledge. The student estimates, answers, and solves proportion and ratio problems by replicating the proportion or ratio repeatedly with the support of materials.

See *Teaching Fractions, Decimals, and Percentages* (**www.nzmaths.co.nz/Numeracy**), especially pages 5–12.