Science in "Harnessing the Wind"

Possible achievement objectives

Science

Nature of Science

Investigating in science (IiS)

- L1 and 2: Extend their experiences and personal explanations of the natural world through exploration, play, asking questions, and discussing simple models.
- L3 and 4: Ask questions, find evidence, explore simple models, and carry out appropriate investigations to develop simple explanations.

Physical world

Physical inquiry and physics concepts (PI&PC)

- L1 and 2: Explore everyday examples of physical phenomena, such as movement, forces, electricity and magnetism, light, sound, waves, and heat.
- L1 and 2: Seek and describe simple patterns in physical phenomena.
- L3 and 4: Explore, describe, and represent patterns and trends for everyday examples of physical phenomena, such as movement, forces, electricity and magnetism, light, sound, waves, and heat. For example, … identify and describe everyday examples of sources of energy, forms of energy, and energy transformations.

Material World

Properties and changes of matter (P&CoM)

- L1 and 2: Observe, describe, and compare physical and chemical properties of common materials and changes that occur when materials are mixed, heated, or cooled.

The structure of matter (SoM)

- L4: Begin to develop an understanding of the particle nature of matter and use this to explain observed changes.

Chemistry and Society (CaS)

- L1 and 2: Find out about the uses of common materials and relate these to their observed properties.
- L3 and 4: Relate the observed, characteristic chemical and physical properties of a range of different materials to technological uses and natural processes.

Key ideas

Nature of Science

- Scientists identify trends and patterns when exploring natural phenomena.

- Scientists use the trends and patterns to generate questions whose answers will help them create explanations and make sense of their observations.
- Scientists check their explanations by collecting further data to back up or refute their initial evidence.
- Scientists record and share both their explanations and the processes they used to test their ideas with other interested scientists and the general public.

Physical and Material World

- Air is a mixture of gases that forms the atmosphere that surrounds planet Earth.
- Wind is created when air particles move.
- For air particles to move, there needs to be a source of energy.
- Energy makes things happen by generating forces that do work.
- Energy comes in many forms.
- Energy cannot be created or destroyed, but it can be transformed from one form to another.
- Forms of energy include mechanical, heat, light, chemical, sound, electrical, and nuclear energy.
- Scientists and technologists use their knowledge of the physical and chemical properties of materials when seeking explanations for their observations and suggesting solutions to problems and needs.

Developing the key ideas

Exploring and explaining the science

Learning Goals (to be shared with your students)

In this activity, we are learning to:

- **explore and explain natural phenomena in a scientific way (IiS)**
- **identify and test the evidence to inform our understanding of the forces and energy involved when using wind power as a source of energy (IiS)**
- **make connections between the science ideas and concepts we are exploring and examples from our everyday lives (IiS).**

Exploring air and energy

These hands-on, interactive activities will allow your students to explore the phenomena that are involved in producing electrical energy though the use of wind turbines. The activities will help them to clarify their existing thinking and to develop scientific explanations for the phenomena. As the students proceed through this exploratory phase, have them record tentative, new, or modified explanations for the phenomena that they are investigating. Where possible, present the scientific explanations to your students' spontaneous questions as they arise.

Focus questions

- *What is air?*

- *What causes air to move as wind?*
- *What is energy?*
- *Can we identify examples of types of energy and energy transformations?*
- *What are some of the ways can we use wind energy to make things work?*
- *How does a wind turbine work?*

Establishing that air exists and identifying some of its properties

Pack a crushed paper towel into a jam jar and then immerse the jar, upside down, in a large container of water until the whole jar is submerged. Remove the jar, without tipping it, and observe the state of the paper. The paper will remain dry. Ask the students to suggest an explanation for their observations. *(The air in the jam jar provides a barrier between the paper towel and the water, thus keeping the towel dry.*)

Repeat the process, using a plastic cup. First, demonstrate that the paper towel remains dry as before, and then, make a small hole in the base of the cup. Ask the students to watch closely. As the cup is submerged, they should see small bubbles of air rising up from the cup.

Remove the cup. This time the paper towel will be wet.

Ask the students to provide a tentative explanation of what air is. *(The atmosphere is a mixture of gases that surround Earth like a blanket. It is kept in place by the force of gravity.)*

Blowing air through a straw

Have the students blow gently onto the back of their hand, using a short length of straw. Establish with your students that air is made up of tiny particles that they can feel hitting their hand. Link this to their experiences of wind blowing on a windy day.

Using a balloon to demonstrate what happens to air when it is heated

Take two soft-drink bottles and place a balloon over the mouth of each. Immerse one of the bottles in a container of hot water and the other in a container of water at room temperature. Before doing this, ask the students to predict what will happen and why.

Ask the students to watch the balloons carefully. Photograph or video what happens to use as evidence later. Ask the students to provide their own explanations of what caused the balloon to expand. Compare their ideas with the accepted scientific explanation. (*The air inside the bottle heats up, the increased energy causes the particles of air to move more quickly, and in doing so, they create greater pressure and take up more space.*)

Role-play: Modelling a scientific idea

Have the students role-play what happened to the air inside the bottle when the bottle was immersed in the water. About ten students, each representing an air particle, stand together in a group, just touching, to model the air at room temperature. As the air is heated and increases its energy, they begin to vibrate on the spot, gently at first and then more vigorously. Finally, the group spreads out and takes up the available space. Encourage the students to come up with their own analogies and models to explain what happens to the particles in air when it is heated.

A strong wind

Drop a small, lighted taper into a bottle and then place a shelled, boiled egg or a water bomb over the bottle's opening. As heated gas is escaping, the taper will burn out and the egg or water bomb will be sucked in. This happens because of the change in pressure. When the air is heated up, it expands, taking up more space. As a result, much of it escapes out of the jar. When the taper goes out, the air cools and heat energy is reduced. The particles inside do not need as much space, so the pressure drops. The air outside is like a very strong wind. It pushes the egg into the bottle as it tries to move from a higher pressure to a lower pressure.

What is wind?

Wind is moving air, the result of differences in air pressure caused by heat energy. As air is heated, it takes up more space, becomes lighter per volume, and rises as a result. Its space is taken up by air moving in convection currents to take its place (see "Harnessing the Wind", pages 3 and 4). Moving air becomes a force that can move and turn other things, such as a leaf, a sailboat, a windmill, or a wind turbine. The moving turbine can be used to transform the wind energy into electrical energy, which can then be used to make machines work and provide heat and light.

Exploring energy

By generating forces, energy causes things to happen and change.

We can't see energy itself – only the results of energy being used or transformed – so students will need to be introduced to the concept of energy in a more abstract manner. Spend time exploring and working with the science vocabulary involved.

Divide the class into groups. Provide a variety of magazines or newspapers and ask each group to cut out any images showing examples of forms of energy. Ask them to classify the images into groups under the following headings:

- Mechanical energy
- Heat energy
- Light energy
- Chemical energy
- Sound energy
- Electrical energy
- Nuclear energy
- Kinetic energy.

(Kinetic energy is energy associated with movement. It encompasses and is integrated with many of the other types of energy.)

Have each group create posters or another means of displaying their images, and then have them present and discuss their examples with the class.

How does energy move?

Using the group posters, ask the students to explore each example and decide how the energy is being transformed and how it moves.

Give each group a set of labels on sticky notes:

- conduction

- convection
- radiation
- vibration.

Ask them to place the notes on the charts to show the process by which the energy is moving and the form to which that energy is changed.

A useful culminating activity would be to ask the students to imagine they live in a remote country district that is not connected to the national electricity network. Their house is powered by electricity that is generated by a wind turbine. Their grandmother has written and asked them how they cook their food, read their books, and watch TV, using only the wind. Ask the students to prepare a presentation that will explain to their grandmother how wind energy is produced and transformed into different types of energy. They should use photographs, diagrams, role plays, models, and appropriate scientific terms in their explanation.

Testing our explanations

In this section, the students plan and carry out a scientific inquiry to test the explanations they arrived at in the previous activities (Exploring Air and Energy). At levels 1 and 2, this can be a whole-class inquiry, but at levels 3 and 4, the students should be moving to scaffolded and supported group investigations. It is important that they communicate their findings to the class and that other students evaluate, ask questions, and provide feedback on these findings (in the same way that scientists have their work evaluated by other scientists in the scientific community).

Devise questions to test out the students' thinking behind the explanations they provided, or select questions to be investigated from those that arose during the exploratory phase. For example:

Focus question

What does convection look like?

The modelling of convection currents presented on page 4 of the students' book is a very useful example of finding the answer to a question by modelling an event or phenomena and observing and recording what occurs.

Ask the students to make predictions about what will happen if any of the conditions are changed. For example, ask them: *"Will convection happen without having a heat source below the tank?"*

This could lead into more formal testing of the students' explanations and thinking, through a systematic process of inquiry. *Making Better Sense of the Physical World*, pages 13–16, provides a useful framework for investigating ideas about the physical world.

The New Zealand Curriculum Exemplars (Investigating in Science Matrix) also provide a useful set of learning indicators that can be used for giving formative feedback while the students are planning and doing their investigations. The science matrices are available at:
http://www.tki.org.nz/r/assessment/exemplars/sci/matrices/index_e.php

Further activities

1. Exploring turbine blades

Brainstorm all the variables associated with the blades on a turbine including size, materials, length, and balance. Explore ways to construct working blades and identify what variables could be changed, measured, and tested. Then plan and carry out a series of fair tests to evaluate the effectiveness of the different combinations.

2. More for super science sleuths

Other phenomena that could be the focus for investigation include the properties of various materials used for:

- conducting various forms of energy (such as electricity or heat energy or transmitting sound waves);
- causing the transformation of energy (such as electrical energy transformed to heat energy in toasters or heat energy from the sun transformed to the energy used by Daniel Carter when kicking a goal).

Ministry of Education resources

Building Science Concepts Book 54: *Windmills and Waterwheels* provides a specific context for exploring the harnessing of energy from wind and water. It could be used as a stand-alone resource to guide the learning for students working at levels 3 and 4. Alternatively, it could be used as part of a wider investigation of what wind is and how is it formed.

Ministry of Education (2004). *Windmills and Waterwheels: Harnessing the Energy of Wind and Water.* Building Science Concepts Book 54. Wellington: Learning Media.

Ministry of Education (2003). *Solar Energy: Sun Power on Earth.* Building Science Concepts Book 29. Wellington: Learning Media.

Ministry of Education (2003). *The Air around Us: Exploring the Substance We Live in.* Building Science Concepts Book 30. Wellington: Learning Media.

Ministry of Education (1999). *Making Better Sense of the Physical World.* Wellington: Learning Media.

> PDFs of the Material World and Physical World books in the Making Better Sense series are available online from the Ministry of Education's The Science Toolbox webpage at: http://www.minedu.govt.nz/NZEducation/EducationPolicies/Schools/PublicationsAndResources/ScienceToolbox.aspx

Ministry of Education (1995). *Wind Power* (Ready to Read series). Wellington: Learning Media.

For up-to-date support for schools and teachers in the implementation of the technology curriculum, including explanatory papers and indicators of progression, look under Curriculum at: http://www.techlink.org.nz

Other resources

Henderson, J (1998). *Wind Power* Alpha 95 Alpha Series. Wellington: The Royal Society of New Zealand (available from www.rsnz.govt.nz/shop/index.php)

Websites

www.energywise.org.nz

www.eeca.govt.nz

www.windenergy.org.nz

www.kidwind.org/

Technology in "Harnessing the Wind" and "Wind Power: The Debate"

The following notes are designed to be used with "Harnessing the Wind" and "Wind Power: The Debate". The two articles should be read together.

Possible achievement objectives

Nature of Technology

Characteristics of technology (CoT)

- L3: Understand how society and environments impact on and are influenced by technology in historical and contemporary contexts and that technological knowledge is validated by successful function.

Key ideas

- Societal and environmental issues can influence what technological outcomes are made and how they are made.
- Technological outcomes change over time.
- Technology impacts on the social and natural worlds over time.
- Technological knowledge is knowledge that technologists agree is important because it ensures the success of a technological outcome.

Developing the ideas

Technology, society, and the environment: Evaluating the success of technological outcomes

Learning Goals (to be shared with your students)

In this activity, we are learning to:

- **describe how society and environmental issues can influence what technological outcomes are made and how they are made (CoT)**
- **explain why technological outcomes change over time (CoT)**
- **describe examples of how technology has impacted on the social world over time (CoT)**
- **describe examples of how technology has impacted on the natural world over time (CoT)**
- **identify that technological knowledge is knowledge that is useful in ensuring that a technological outcome is successful (CoT).**

The learning goals listed above are for students working at level 3 of the curriculum. Establish that your students have robust understandings at level 2 before planning to progress their understanding at level 3.

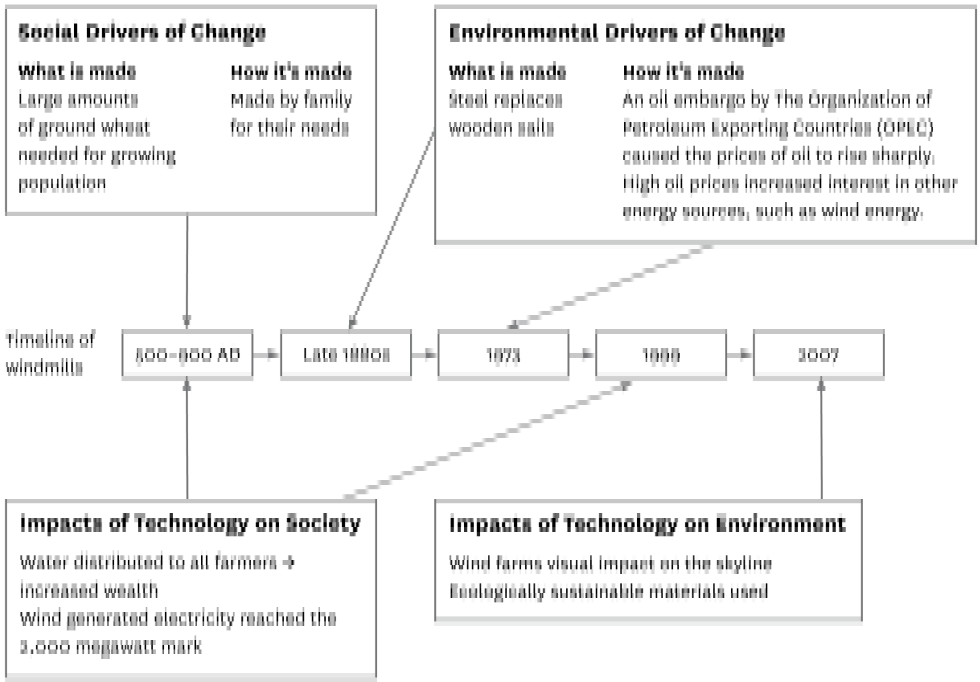
We generate energy to enable us to live in ways that ensure our survival and comfort. In order to generate this energy, we need to understand the relationships between people, the environment, and the made world.

After reading both articles, ask the students to construct a timeline to show how people have used the power of wind. Some useful references are:

- http://en.wikipedia.org/wiki/History_of_wind_power
- http://en.wikipedia.org/wiki/Windmill
- http://www.telosnet.com/wind/

In groups, first have the students discuss how technological outcomes that use the power of wind have changed over time. Ask them to identify how each outcome changed how people do things (level 2 CoT). The students should use the timelines and *Connected* 3 articles to do the following tasks: [Web developer: Please add hyperlink from technological outcomes above to definition on p62 of these notes.]

- Look at your timeline and record why you think the outcomes changed over the years. (Encourage the students to think about changing needs, environmental factors, resources available, knowledge and developments in technology and science, and the impact of technological outcomes on society and the environment.)
- Organise the points listed above in a timeline or a concept organiser. For example:



Students will need to be supported in this task. Discuss key words such as:

- drivers
- social or environmental drivers
- impacts.

Ask the students to list all the knowledge that was useful when developing the technological outcomes. Was there any knowledge that in hindsight was missing (or not known) that may have meant an outcome did not work as it should or resulted in its failure over time? For example, using wood to make cogs would result in their failure over time. Was metal available? Did the people have the tools and knowledge to work with metal? Guide students to understand that technological knowledge is the knowledge that technologists value and use because it ensures a successful outcome.

Examples of knowledge that is useful in wind-operated technological outcomes could include:

- developing and using models
- understanding technological systems
- understanding what people want or need
- understanding the properties of the materials used
- understanding what jobs need to be done or what problems need to be solved
- scientific knowledge of electricity generation, wind patterns, gearing, and geology
- mathematics.

Further activities

Other Outcomes

Students could choose another technological outcome that has changed over time, as the needs of society and environmental issues have changed, and repeat the activity described above. Examples of other outcomes they might study could include:

- the telephone
- the washing machine
- devices that play recorded music
- the car
- items that we eat for lunch
- chairs.

Further references (below) provides a list of useful websites for this activity.

Ministry of Education resources

See Explanatory Papers and Indicators of Progression for characteristics of technology under Curriculum at www.techlink.org.nz for further support.

Windmills and Waterwheels: Harnessing the Energy of Wind and Water. Building Science Concepts, Book 54.

Other resources

- www.designboom.com/eng/education/foldingchair.html
- www.yourdiscovery.com/cars/timeline
- http://inventors.about.com/od/bstartinventors/a/telephone.htm
- www.telephonymuseum.com/telephone%20history.htm
- www.ideafinder.com/history/inventions/washmachine.htm
- www.thepeoplehistory.com/hifi.html
- www.foodtimeline.org

Mathematics in "Harnessing the Wind"

Possible achievement objectives

Statistics

Statistical investigation (SI)

- L2: Conduct investigations using the statistical enquiry cycle:
    - posing and answering questions
    - gathering, sorting, and displaying category and whole-number data
    - communicating findings based on the data.

Number and Algebra

Number strategies (NS)

- L3: Use a range of additive and simple multiplicative strategies with whole numbers, fractions, decimals, and percentages.

Number strategies and knowledge (NS&K)

- L4: Use a range of multiplicative strategies when operating on whole numbers.
- L4: Find fractions, decimals, and percentages of amounts expressed as whole numbers, simple fractions, and decimals.
- L5: Use rates and ratios.

Patterns and relationships (P&R)

- L4: Generalise properties of multiplication and division with whole numbers.

Geometry and Measurement

Measurement (M)

- L3: Use linear scales and whole numbers of metric units for length, area, volume and capacity, weight (mass), angle, temperature, and time.

Key Ideas

- When two objects travel at the same velocity, the one with the greater mass has the most energy. We can calculate the kinetic energy of an object if we know its velocity and mass.
- Graphs are valuable mathematical tools for observing trends. We can graph data to compare how changes in particular factors affect energy production or technological performance.
- Different types of graphs display the same data in different ways. When choosing the type of graph to use, we should consider which is most appropriate for the information we want to show.
- By using cog-wheels of different ratios, we can change the power delivered by a machine.

- To gain the maximum generating capacity from wind turbines, gear systems are used.

Developing the ideas

The following mathematics ideas and activities cover a range of curriculum levels up to level 5. Curriculum levels are indicated in brackets. Choose from the activities, depending on the curriculum levels at which your students are working.

1. Making energy comparisons

Learning Goals (to be shared with your students)

In this activity, we are learning to:

- **record our observations and use that data in a table to compare the kinetic energy of various objects (M, SI)**
- **use line graphs and bubble graphs to display information and compare data (SI).**

(Level 3 Statistical investigation, Level 3 Measurement)

Focus question

- *What is the mass of the atmosphere?*

Kinetic energy is dependent upon two variables: velocity and mass. If we can make velocity constant, we can measure the effect of the mass of various objects on the kinetic energy they produce.

Refer to "Galileo's Experiment" on page 17 of *Connected* 3 2009, which explains how Galileo showed that all objects fall at the same speed (or acceleration). To confirm Galileo's findings, the students could repeat his experiment. Have them drop two objects of the same size but different mass from a height of 2 to 3 metres (the back of a tiered sports seating stand is ideal). To nullify the effect of air resistance, both objects should be of a similar shape. A golf ball and a similar-sized rubber ball are ideal.

Drop each object five to ten times, using a stopwatch to time each fall.

Record the data in a table like the one below and then calculate the average time it took for each object to fall.

	golf ball (time in seconds)	rubber ball (time in seconds)
Observation 1	0.75	0.73
Observation 2	0.73	0.68
Observation 3	0.68	0.82
Observation 4	0.81	0.81
Observation 5	0.70	0.78
Average	0.73	0.76

The students should be able to see that both balls took the same time to fall (within an acceptable margin of error). Therefore, they must be travelling at the same speed when they reach the ground.

Note: The greater the height from which the balls are dropped, the easier it will be to time their fall. However, ensure student safety at all times.

Have the students find the mass of each ball using a sensitive scale. Then, ask them to drop the balls, one at a time, from the same height (1 metre will be sufficient) onto a slab of prepared plasticine.

Drop each ball a number of times and each time measure the depth of the indent it makes in the plasticine. (Balls are good objects to use, as their shape means there is always only one deepest point to measure. Lay a flat ruler across the diameter of the indent and mark the depth on a toothpick.)

Record the data and then find the average depth of indentation for each object.

An example of possible data is shown below.

	Golf ball (45 grams)	**Rubber ball (same size) (20 grams)**
Observation 1	6 mm	3 mm
Observation 2	7 mm	2 mm
Observation 3	5 mm	2 mm
Observation 4	5 mm	3 mm
Observation 5	7 mm	3 mm
Average	6 mm	3 mm

The data shows that when two balls travel at the same velocity, the ball with the greater mass has the most energy.

You could extend this activity by using several balls of the same size but different masses. Plot a graph showing the depth of the dent on the vertical axis and the mass of the ball on the horizontal.

The graph should show that, for balls travelling at a constant velocity, as their mass increases, so does the kinetic energy they produce.

Focus question

- *What is the mass of the atmosphere?*

Discussion arising could cover:

- Does air weigh nothing? Discuss air pressure. Demonstrate a barometer. Why do our ears pop and do funny things when we gain altitude?
- Consider scuba diving tanks. For normal diving purposes, they contain compressed atmospheric air. Why is there a difference in their weight when empty and when full? For a useful article on this, go to: http://en.wikipedia.org/wiki/Diving_cylinder
- Air has mass – the mass of the atmosphere is approximately 5 000 000 000 000 000 000 kilograms or 5×10^{18} kilograms.

Further activities 1–3 also involve the recording of data.

2. Stepping it up (exploring cogs)

Learning Goals (to be shared with your students)

In this activity, we are learning to:

- **understand the effect cog-wheels of different ratios have on the power delivered by a machine (NS&K)**
- **gain the maximum generating capacity from wind turbines, gear systems are used (NS&K).**

(Level 3 Number knowledge, Level 4 Number strategies and knowledge)

Wind turbines use cog-wheels to gear up the number of turns of the blades so that the magnets spinning around in the generator coil do so more rapidly. This increases the generating capacity of the turbine.

Cog-wheels have been around for thousands of years, but for a long time they were only ever used in a ratio of 1:1. Leonardo da Vinci saw the potential of using them with mixed ratios and made several models to explore their possibilities. Illustrations of these can be found at www.macchinedileonardo.com. The models can be constructed fairly easily by anyone with basic woodworking skill.

Provide the students with plastic cog-wheels of various sizes – in particular, they will need:

- a 1:1 ratio
- a simple ratio, such as 2:1, 3:1, or 4: 1
- a complex ratio, such as 3:2 or 2:7.

Before discussing numbers, let the students engage in cog-wheel play. Experimenting with various combinations will help them to develop a physical "feel" for the effect of ratio.

Introduce the terminology "driver gear" (the cog closest to the source of energy when two cogs are placed together) and "driven gear" (the cog receiving the energy).

Give the students two cogs in a 1:1 ratio and then ask them the following questions.

- How does the number of teeth in each of the cogs affect the gear ratio?
- Before Leonardo da Vinci, cog-wheels were only used in a ratio of 1:1. How would this have limited machinery?

Answers could include:

- One turn of the driver gear results in one turn of the driven gear.
- The ratio of the driver gear to the driven gear is 1:1.
- The speeds at which the driver gear and the driven gear turn will be identical.
- Machinery using this sort of gearing would be limited as nothing would be made to turn any faster than the driver gear.
- The machinery would be unlikely to be very powerful.

Give the students two cogs in a 2:1, 3:1, or 4:1 ratio, and then ask them the following questions.

- What happens when the driver gear is the bigger of the two cogs?
- When the driver gear is the bigger of the two cogs, what is the ratio of drive teeth to driven teeth?

Answers could include:

- The driven gear turns much faster than the driver gear.
- For every one turn of the driver gear, the driven gear makes (depending on the number of teeth on the cog) two, three, four, or more turns.
- The ratio of the driver gear to the driven gear is 24:12 (sample values); this can be simply expressed as 2:1 (24 and 12 are both divisible by 12).

Then ask them the following questions.

- What happens when the driver gear is the smaller of the two cogs?
- When the driver gear is the smaller of the two cogs, what is the ratio of drive teeth to driven teeth?

Answers could include:

- The driven gear turns much slower than the driver gear.
- For every two, three, four or more turns of the driver gear (depending on the number of teeth on the cog), the driven gear makes one turn.
- The ratio of the driver gear to the driven gear is reversed; it is now 12:24, which can be more simply expressed as 1:2.

Give the students two cogs in a 7:2 ratio or similar, and then ask them the following questions.

- How many teeth on each cog?
- What is the ratio of these gears?
- When the big cog is the driver cog, how many turns does the driven cog make when the driver cog is turned once?

  (Tip: Making a felt-tip reference mark on the gears will make it easier to count the number of turns.)

Answers could include:

- For every one turn of the driver gear, the driven gear makes three and a half turns.
- For every two turns of the driver gear, the driven gear makes seven turns.
- The ratio of the driver gear to the driven gear is 35:10 (sample) or 7:2.

Notice that gear ratios are representative of the number of teeth on each cog. If we were to consider turns, then it would be the opposite way around. For example, a 72-tooth drive cog linked to a 24-tooth driven cog has the ratio 72:24 or 3:1 (both numbers are divisible by 24). However, if the drive cog is turned once, the driven cog will spin three times.

Further activities 4 explores ratios further.

Further activities

1. Is bigger better?

(Level 3 Patterns and relationships, Level 2-3 Statistical investigation)

Students often struggle with the idea that bigger is not always better. It's not necessarily true that the larger the turbine, the greater the output (see the discussion about optimising wind turbines in the student book, pages 8–9). This can be easily demonstrated by using rubber bands to fire folded paper pellets.

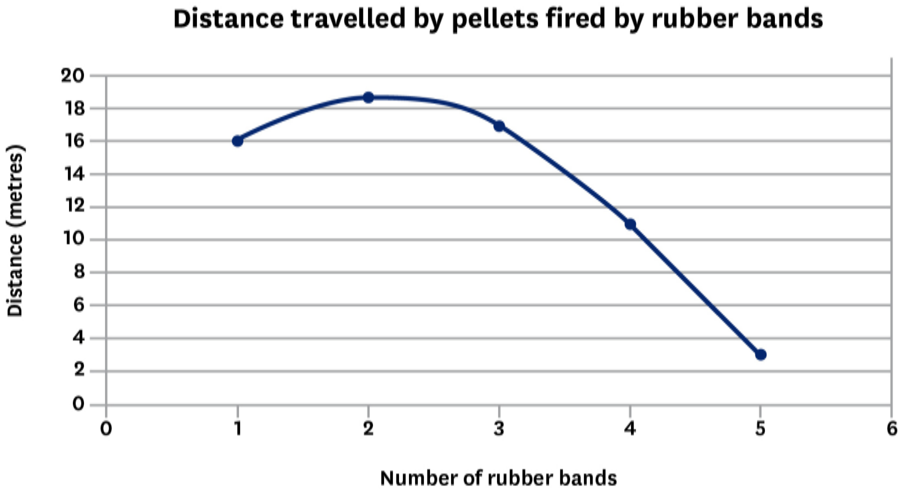
Have a student shoot a pellet using one rubber band and mark the spot where it lands. Then use two rubber bands and see if the pellet travels further. Try three rubber bands, then four, and so on. As more rubber bands are used, it takes more and more energy to pull them back. Multiple rubber bands can't be stretched as far as a single one. Not as much energy gets transferred to the pellet.

Similarly with wind turbines, the bigger the turbine, the more wind energy it takes to get it moving. However, if the turbine is too small, it can't catch enough wind energy to turn the magnets in the wire coils.

The rubber bands experiment also provides an opportunity for data gathering and a simple graphing exercise. First have the students record the data in table form as shown below. (The data will vary depending on the type of rubber band used, but the trend should be similar.)

Number of rubber bands	Distance of pellet
1	16 m
2	19 m
3	17 m
4	11 m
5	3 m

Then ask them to display the data by drawing a simple line graph.



2. Pinwheel blades and the speed of rotation

(Statistical investigation level 2)

As a further activity, students could compare the number of blades on a pinwheel to the speed at which it rotates. Information on how to make a pinwheel can be found at http://www.leslietryon.com/3dcolorcutout/makepinw/makepinwheel.html

- Make four pinwheels: the first with one blade, the second with two blades, and so on.
- Hold the pinwheels up to an electric fan and make qualitative statements about the speed at which they turn, for example, slow, medium, and so on.
- Rank the pinwheels in order of efficiency, based upon the number of blades they have.
- An interesting discussion could be held about balancing pinwheels. There will be a vast difference in performance between a two-blade pinwheel on which both blades are adjacent and one on which the two blades are diagonally opposite one another.
- This could lead on to a discussion about the role of symmetry for turbines and other machines.

3. Variations on the convection tank experiment

(Level 4 Statistical Investigation, Level 4 Measurement)

Repeat the convection tank experiment (page 4 of the student book) using different heat sources. These might include:

- a hand
- a hairdryer
- an electric blanket.

Measure the temperature of each heat source and then observe the effect that it has on the red and blue dyes in the water. Draw up a table like the one below and enter the data from your observations. (The data shown is estimated. Recordings will vary, depending on such variables as the size of the tank.)

Heat source	Temperature	Time taken for the red dye to reach the ice block	Time taken for the blue dye to reach the "red corner"	Time taken for the red and blue dyes to be completely mixed
Hand	30° C	6 min	6.5 min	28 min
Hairdryer	150° C	3.5 min	3.0 min	17 min
Electric blanket	45° C	5 min	5.5 min	22 min

Students could also measure the temperature at various points inside the tank at given time intervals and represent the data graphically.

Fix a number of thermometers at selected points inside the tank, for example:

- submerged near to the heat source (A);
- at the surface, directly above the heat source (B);
- close to the ice block (C);
- submerged directly beneath the ice block (D).

Use retort stands to secure the thermometers.

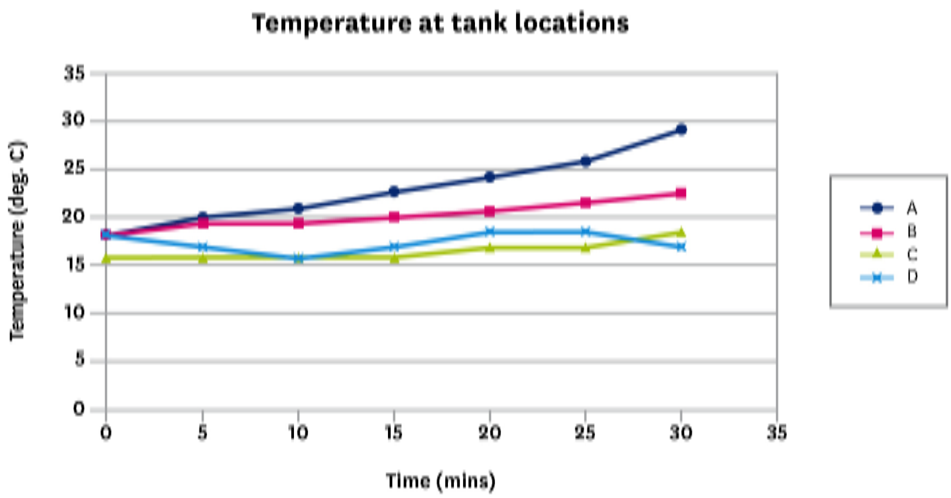
Start the experiment and record all data at regular time intervals. An example is shown below.

Heat source: hairdryer

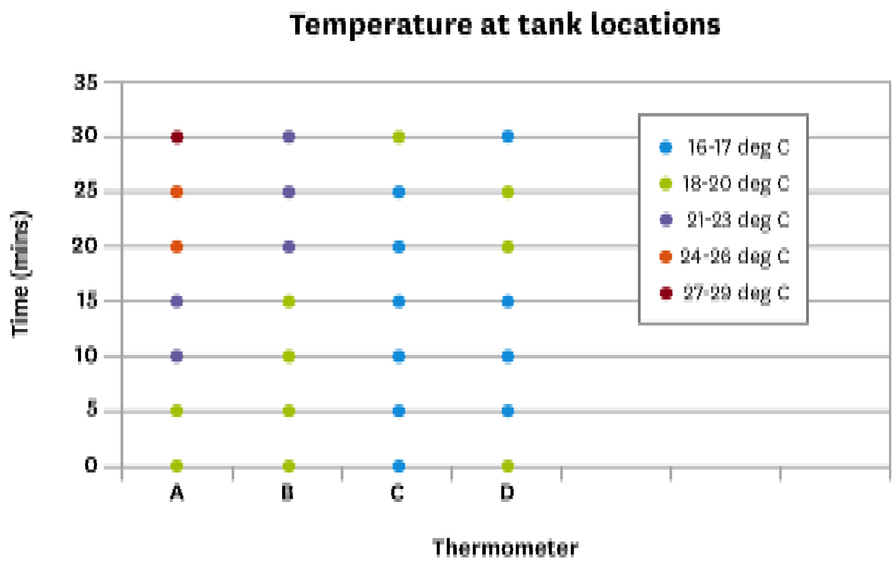
Elapsed time in minutes	Temperature in degrees Celsius			
	A	B	C	D
0	18	18	16	18
5	20	19	16	17
10	21	19	16	16
15	23	20	16	17
20	24	21	17	18
25	26	22	17	18
30	29	23	18	17

Represent this information graphically using a multiple-line graph or a bubble graph.

Multiple line graph



Bubble graph



In this bubble graph, the *y*-axis represents the time elapsed and the *x*-axis shows the individual thermometers. A colour code is used to show temperature ranges. The coloured bubbles display the temperature changes at the various locations with respect to time.

4. Ratio table

(Level 3 Number knowledge, Level 4 Number strategies and knowledge)

To reinforce the concept of ratios, ask the students complete the following table. Where appropriate, have them use actual cogs to test their calculations.

Driver (number of teeth)	**Driven gear** (number of teeth)	**Ratio**	**Simplified ratio**	**Rotations** (number of turns of the driven gear for each turn of the driver gear)
40	20			
8	40			
24	8			
12	36			
36	6			
6	24			

Ministry of Education Resources

"Jumping for Joules" in *Connected 3 Teacher Support Materials* 2008 (For more activities with ratios)

"A New Life for Old Machines" in *Connected 3 Teacher Support Materials* 2007 (For more activities about turbines, alternative sources of energy to fossil fuels, and conserving electricity)

Connected Teacher Support Materials are available online at: http://www.tki.org.nz/r/technology/connected/index_e.php

You can find an alternative version of this activity in "Gearing Up" from the Ministry of Education's Figure It Out series: *Forces Level 2+–3+* (Science theme).

For more related activities, see:

"The Right Gear" in Figure It Out *Proportional Reasoning Book 2 Level 3–4*.

"Biscuit Factory", (gears and ratios) available from the Ministry of Education's digital resources site at http://digistore.tki.org.nz/ec/p/home