More than a Box

by Dave Armstrong

CONNECTED 2
SCIENCE • TECHNOLOGY • MATHEMATICS

Overview

"More than a Box" describes the processes and practices used when planning, designing, and building a large indoor sports centre. It outlines the science and technology behind the building process, including the steps taken to ensure that the structure remains erect, stable, and safe.

Curriculum context

SCIENCE

MATERIAL WORLD

Chemistry and society

Achievement objective

L3: Students will relate the observed, characteristic chemical and physical properties of a range of different materials to technological uses and natural processes.

PHYSICAL WORLD

Physical inquiry and physics concepts

Achievement objective

L3: Students will explore, describe, and represent patterns and trends for everyday examples of physical phenomena, such as movement [and] forces …

Key ideas

- Structures (both living and non-living) need supporting frameworks to counter natural forces such as gravity and earthquakes.
- When designing and building structures, engineers use their knowledge of building techniques and the properties of materials.
- Structures can be strengthened by bracing and suitable foundations.

Learning goals (to be shared with your students)

In this activity, we are learning:

- to explore properties of building materials and how this knowledge is used when structures are being designed and built
- to plan and carry out investigations to test our understanding of the impact gravity and earthquakes have on both living and non-living structures.

NATURE OF SCIENCE

Communicating in science; investigating in science

Achievement objectives

L3: Students will begin to use a range of scientific symbols, conventions, and vocabulary.

L3: Students will ask questions, find evidence, explore simple models, and carry out appropriate investigations to develop simple explanations.

Key idea

- Scientists and engineers seek to understand natural phenomena. They repeatedly test the evidence they use when constructing models and formulating their explanations.

Learning goals (to be shared with your students)

In this activity, we are learning:

- to develop an understanding of the processes engineers and scientists use when planning and conducting investigations
- to test the evidence we use when formulating our explanations
- to use annotated drawings to share our explanations of the forces acting on structures in the environment.

MATHEMATICS AND STATISTICS

GEOMETRY AND MEASUREMENT

Shape

Achievement objective

L3: Students will classify plane shapes and prisms by their spatial features.

NUMBER AND ALGEBRA

Patterns and relationships

Achievement objective

L3: Connect members of sequential patterns with their ordinal position and use tables, graphs, and diagrams to find relationships between successive elements of number and spatial patterns.

Key ideas

- Any shape can be strengthened by adding diagonal braces.
- A triangle is the strongest shape.

Learning goals (to be shared with your students)

In this activity, we are learning:

- to identify and classify shapes and prisms according to recognisable attributes
- to draft drawings of structures using geometric shapes and a sense of scale.

STATISTICS

Statistical investigation

Achievement objective

L3: Students will conduct investigations using the statistical enquiry cycle:

- gathering, sorting, and displaying … data …
- communicating findings, using data displays.

Key ideas

In buildings, a triangle is the only polygon that retains its shape under pressure. Other polygons such as rectangles can be used provided diagonal braces are added to create internal triangles.

- any shape can be strengthened by adding diagonal braces.

Learning goal (to be shared with your students)

In this activity, we are learning:

- about a special property of triangles
- to find a rule that describes a pattern.

ENGLISH

READING

Processes and strategies

Achievement objective

L3: Students will integrate sources of information, processes, and strategies with developing confidence to identify, form, and express ideas.

Indicator

- Integrates sources of information and prior knowledge with developing confidence to make sense of increasingly varied and complex texts.

Ideas

Achievement objective

L3: Students will show a developing understanding of ideas within, across, and beyond texts.

Indicator

- Starts to make connections by thinking about underlying ideas in and between texts.

The Literacy Learning Progressions

The relevant knowledge, skills, and attitudes for students at this level are described in the The Literacy Learning Progressions.

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Suggestions for providing literacy support for the key ideas

The following strategies will support students to engage with the ideas and information as they use the text for particular curriculum purposes.

The *Connected* series includes a range of texts that provide opportunities for students to locate, evaluate, integrate, and synthesise information and ideas.

It is expected that students will read across the range of texts in this *Connected* to develop their literacy skills and their understanding of the topic.

Text characteristics

- Abstract ideas, in greater numbers than in texts at earlier levels, accompanied by concrete examples in the text that help support the students' understanding
- A significant amount of vocabulary that is unfamiliar to the students (including content-specific words and phrases), which is generally explained in the text by words or illustrations
- Sentences that vary in length and in structure
- Photographs and diagrams that clarify or extend the text and may require some interpretation.

1. FINDING THE MAIN IDEAS

This article describes the challenges of designing and of building a large sports centre.

The main ideas in the text include:

- When designing a building, architects and engineers have to ensure that it will be strong, fit for its purpose, and safe.
- Engineers use models of their designs to test a whether a building's structure will be safe and strong.
- The framework of a building functions like a skeleton.
- Materials used in buildings are chosen for their performance qualities.
- Triangular shapes are often used to make buildings strong because triangles are the only polygons that keep their shape under pressure.

MODEL ways in which students can organise the information they are reading.

Challenge	Solution
How to provide an interesting design	Using a mussel shell shape
How to hold up the roof	Columns in the centre of ·the building connected to columns at the sides by steel trusses
How to resist strong winds	Putting a model of the building in a wind tunnel to see which parts would be vulnerable Using deep, concrete foundations

PROMPT students to refer carefully to the photographs to make meaning of the text from page 24 onwards.

Look at the oval-shaped trusses in the main photograph on pages 24 and 25. Can you see where the two halves of each truss have been welded together? Count the number of diagonal steel rods in each truss.

EXPLAIN to the students how turning the headings into questions can help to predict the main focus of each section. **MODEL** how to ask questions from headings. For example:

This heading is "Using models to help". If I ask "How does using models help (when building something)?" this gives me a focus for reading. Now I am looking for information that answers my question as I read.

2. DEALING WITH UNFAMILIAR VOCABULARY

IDENTIFY and **LIST** the challenging vocabulary.

Have the students develop their own glossaries of unfamiliar words, or develop one together.

PROMPT the students to seek definitions of these words in the text and in the photographs.

The text explains some of these words and phrases, but sometimes you have to infer the meanings from what you are reading. The photographs will help you to work out what some of the building items look like.

ASK QUESTIONS to promote discussion of the meanings of the construction verbs.

Has anyone seen something being welded?

What sorts of materials are welded?

Why would they use a rectangular box to cast the concrete?

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Exploring the science

The following activities and suggestions are designed as a guide for supporting students to develop scientific explanations of the physical world.

Key ideas

- Structures (both living and non-living) need supporting frameworks to counter natural forces, such as gravity and earthquakes.
- When designing and building structures, engineers use their knowledge of building techniques and the properties of materials.
- Structures can be strengthened by bracing and suitable foundations.
- Scientists and engineers seek to understand natural phenomena. They repeatedly test the evidence they use when constructing models and formulating their explanations.

Introduce the idea that natural forces impact on both living and non-living structures. Draw out students' experiences of the effects of such forces and also their knowledge about building, including their observations of building sites or large halls and sports centres.

Activity 1: *Testing shapes, beams, and the role of bracing*

Ask the students to construct a square out of strips of card and adhesive tape or paper clips. Holding their square upright, they should then push it on one side. Establish that when they do this, their square changes shape.

As a class, discuss how an engineer would make a structure of the same shape more stable (see pages 26 and 27 of "More than a Box").

They can then make another square using bracing. Again, they can test it by pushing it on one side. Prompt them to discuss what they have discovered.

Next, they can carry out a similar exploration using an empty cardboard carton. Ask them to open out the interlocking pieces at the top and bottom of the carton and lie it on a table. They can then push the carton on its side and notice how it squashes flat quite easily. Advise them to tuck the end flaps in and secure them with tape, before testing how rigid it has now become.

Some other hands-on activities on this topic are outlined in Building Science Concepts Book 51, *Standing Up: Skeletons and Frameworks,* pages 11–15.

Activity 2: *Building a structure*

Challenge the students to build a structure using a set number of pieces of newspaper and 1 metre of masking tape. Their structure must support a nominated load at least 20 centimetres off the ground.

The students can then explore each other's structures and identify any aspects that helped them to carry the load. Prompt them to look for aspects such as framework, the use of different shapes, bracing columns, beams, and some form of foundation or attachment to the surface.

Activity 3: *Covering the gap*

In the article "More than a Box", the engineers had to design a roof that covered a large space. They designed trusses that were internally strengthened with triangular bracing and supported at each end by a column.

To further explore the principles behind these structures, the students can work in groups. Provide each group with masking tape and a range of other materials, such as strips of paper, cardboard, iceblock sticks, bamboo meat-skewers, and rulers.

Challenge each group to construct a truss to cover the gap between two tables and then to test their truss to identify the maximum load it can support. The truss must support its own weight and that of the load, that is, it should not sag in the middle.

Have each group review their work and that of the other groups, identifying successful techniques and then making refinements to their construction. Alternatively, the students could repeat meeting the challenge, using their new-found knowledge to make improved structures.

As a class exercise, identify and record aspects of the students' structures that helped the structures to support a maximum load.

Activity 4: *Exploring foundations*

The composition of Earth's surface can influence the type of foundations required to ensure a building remains stable. Posts, piles, and poles are often used to provide a foundation support for houses in New Zealand. How deep should foundation posts be?

Have the students fill an ice cream container with sand, another with soil, and a third with builders' mix. They can then push iceblock sticks or pieces of dowel into the three mixtures to a variety of depths.

Have them use a force metre to test how much force is required to pull over each stick or piece of dowel. Repeat the test a number of times and record the results in a table. Discuss any trends and patterns.

Repeat the test, but this time, mix water with the three materials and leave the sticks in place for 24 hours before testing.

Ask the students to explain any differences in the results and make suggestions as to how engineers and builders use this kind of information.

Activity 5: *Exploring fasteners*

Ask the students to design an investigation to test the strength of a range of common fasteners by using them to fasten two pieces of timber together. The fasteners can include nails, nail plates, screws, nuts and bolts, masking tape, and adhesives. (It may be appropriate to invite a person with building skills to work with the students.)

Activity 6: *Testing our thinking*

In groups, have the students discuss what they have learned from their reading and from the previous activities and then decide on an aspect of building construction to investigate further. This investigation could be to:

- answer questions they may have
- provide evidence to confirm generalisations they have made
- explain any trends or patterns they have observed.

The investigation could use practical modelling and testing of the model's attributes.

For example, a designer of a girder, beam, or truss to support a roof might reason as follows:

- We know that box girders are strong.
- We know that triangular shapes can be used to make structures more rigid.
- We think that a truss with triangular bracing will be the strongest form of roof support.

The students could plan and carry out an investigation to test these ideas and then share their findings with the class.

A useful framework for investigating in science is detailed in the Ministry of Education resource *Making Better Sense of the Physical World* (1999), pages 13–15.

"A Sprinkle Here, a Sprinkle There" (*Connected* 1 2004, pages 22–25) also has a clear account of planning and carrying out a scientific investigation.

Further activities

The traditional story of the three little pigs can provide an engaging context for applying the ideas the students explored during this study. The students could redesign the pigs' houses using their knowledge of frameworks, bracing, and foundations and any other ways that the support properties of building materials can be increased. They could then build and test their designs using a fan to generate wind.

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Exploring the mathematics

In buildings, a triangle is the only polygon that retains its shape under pressure. Other polygons such as rectangles can be used provided diagonal braces are added to create internal triangles.

The following activities and suggestions are designed as a guide for supporting students to explore, in a practical, hands-on manner, the mathematical ideas associated with the use of geometric shapes and spatial sense.

The science activities suggested to support the article provide additional opportunities to make the practical use of mathematics explicit as the students reflect on and explore mathematical elements such as position, direction, and orientation. They can also use their statistical skills and knowledge to gather, record, and represent data.

Key ideas

- any shape can be strengthened by adding diagonal braces.
- A triangle is the strongest shape.

MATHEMATICAL IDEAS AND LANGUAGE

- Spatial attributes of objects
- Properties of objects

FOCUS QUESTIONS

- How do the shapes of objects influence their stability and strength?
- How much can the load capacity of different simple shapes be increased by adding triangular bracing?
- Why are triangles stronger than other shapes?

Activity: *Using Diagonals*

Have the students use strips of cardboard and paper fasteners to create a triangle and a square or use strips from a construction set. Ask them to hold the opposite corners of the square, pushing them towards each other to show that the square can be transformed into a diamond (rhombus). They can then show that the triangle can't be moved in the same way, because when they try to move two angles, the third side holds them in place. This is what makes triangles so strong and explains why they are so important in the design of large structures.

Have the students explore the Building Big website online for an interactive lab comparing the strength of different shapes, at:

http://www.pbs.org/wgbh/buildingbig/lab/shapes.html

They may discover the good news that any polygon can be strengthened by dividing it internally into triangles, using diagonal braces. A square can be strengthened by adding a single diagonal brace that divides it into two triangles. Have the students explore this by fastening a fifth strip of cardboard to the square, joining one pair of opposite corners. They will find that the square can no longer be pushed out of shape.

Have the students investigate the minimum number of diagonals that are needed to brace a pentagon, a hexagon, a heptagon, and an octagon. Can they make a make a rule for a polygon of any number of sides? Will this rule work for polygons that are not regular in shape?

An extension of this activity is to explore the total number of diagonals that can be drawn inside different polygons.

MINISTRY OF EDUCATION RESOURCES

- Building Science Concepts (BSC) series, Book 51: *Standing Up: Skeletons and Frameworks* (2003)
- *Connected* series:
  - *Connected* 1 2004, "A Sprinkle Here, a Sprinkle There"
  - *Connected* 1, 2002, "Finding Shapes in Buildings"
- *Making Better Sense of the Physical World* (1999)
- *The New Zealand Curriculum Exemplars: Science*
- *Structures and Mechanisms: Classroom Practice in Years 1–8* (1999)

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