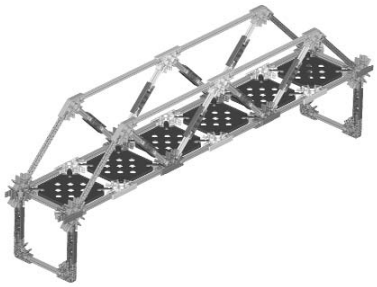
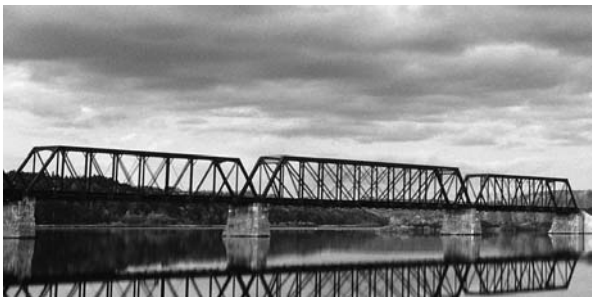
Lesson 4: Truss Bridges

Time: 2 hours or 2 x one-hour lessons

Learning Objectives - Children should learn:

- how structures can fail and explore methods used for strengthening and reinforcing them
- to understand the need for an experimental design that includes a fair test
- to apply what they have learnt by carrying out a simple design and make task
- to work as part of a team





Vocabulary

reinforce, strengthen, diagonal, stable, unstable, stability, framework, lattice, truss, arch, section, square section, ties, strut, beam, horizontal, vertical, model, load, loading, span, triangle, rectangle, force, weight

Resources

Each group of 2-3 children will need:

- *1 K'NEX Introduction to Structures: Bridges set with Building Instructions booklet*
- *Slotted masses or other weights in designated amounts (actual weights: 10-1000grams; books etc.)*
- *String/cord to suspend the weights*
- *Different sizes of square section wood or dowelling*
- *Ruler, pencil, crayons*
- *Paper*

You will need:

- *A dictionary to use as the load for the Design and Build assignment (optional)*

Useful Internet Web Sites

Please refer to the list provided on Page 21 of this Guide. Many of the sites allow the free download of images for educational purposes.

Possible Teaching and Learning Activities

Whole Class

Introduction

- Refer to the investigation carried out in the previous lesson into the strength of beam bridges.

- Discuss possible ways of making a beam bridge stronger/more stable so that it will not bend/fail when heavier loads are carried across wider spans.

Teachers Notes
The children may suggest adding more piers to support the beam, using more rigid materials or making the beam thicker. The optional activity below suggests one way to investigate their suggestions.

The Forces Lab at ***www.pbs.org/wgbh/buildingbig/bridge/*** *provides some very useful background information on this topic.*

You could take this opportunity to introduce the term stability as it relates to bridges. Stability is the ability to resist being deformed or buckled when a force or load is applied.

See: A Quick Guide to Structures: Bridges for additional information.

Optional Activity 1
Whole class demonstration or small group work
Depending on time available, either demonstrate or allow the children to investigate the effect of thickening a beam with respect to its ability to resist bending.

- Provide each group with supplies of different thickness squared section wood, or doweling, a ruler and weights and ask the children to devise a fair test to investigate how thickening a beam affects its ability to resist bending.

Teachers Notes
Possible variables the children may need to think about when devising their test include:
- *The length of beam they will test*
- *The thickness of the beam*

- The following are some questions for the children to consider:
  - How many different thickness sections of wood will be needed to get the information they need to answer the question? Will two thickness sections be enough?
  - How will they measure the 'bending effect'?
  - How will they record and report their results?
- Discuss their findings.

Whole Class
- Ask the class to think of other types of structures that are strong and rigid. What shapes are used in these structures?

Remind the children about the way in which rectangular structures can be made stronger by reinforcing them with diagonal braces (triangulation).

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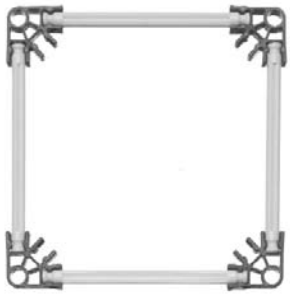
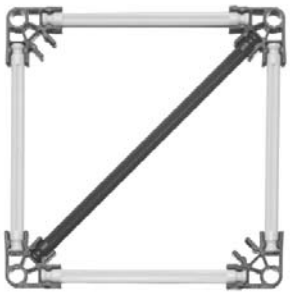
Optional Activity 2
Working in Groups of 2-3

- Children could be allowed the opportunity of investigating this point for themselves by constructing a square from 4 K'NEX Rods (blue) and 4 dark grey 90-degree Connectors.

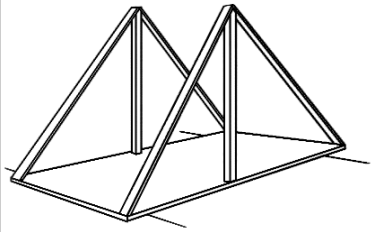
- Encourage them to gently twist and bend the square, then ask them to add one Rod to their square and notice what happens. (They can use a dark grey Rod as a diagonal.)

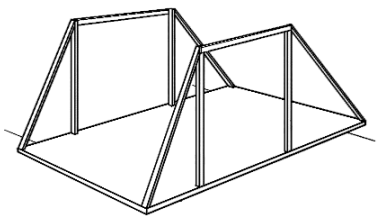
- Ask what shape was formed when they added a Rod to the square.





- Explain how engineers used the strength of triangles to create a framework called a TRUSS. Trusses can be used to build long spans and enhance strength without adding to the weight of the bridge, as a thicker beam would do. The use of triangles helps to keep a structure from bending, twisting or pulling out of shape. The truss bridge was designed as a latticework of triangles and other stable shapes.





- Introduce the ideas of **stable** and **stability** when applied to structures - the ability of structures to be able to resist being deformed significantly, or collapsing, when a load is applied.

- Explain to the children that they will build a number of versions of the truss bridge and will investigate the strength of truss systems.

- Ask the entire class what they think would be a fair test for measuring the strength of the bridges they build. Help them to understand that a fair comparison of the different versions can only be made if testing methods are the same throughout the series of experiments.

Teachers Notes
It is likely that the children will suggest adding weights to measure the strength of the bridges. Ask them to consider how and where they will place the weights. You may want to introduce the term "variable" at this point. Help them to understand that the way in which they place the weights should be the same in every test. In this way, the only variable is the amount of weight and not the way in which the weight is distributed. Hanging the weight underneath the bridge is a more consistent test than placing the weight on the deck or rails. If, however, the weights are hung, the children should ensure that the bridge is spanning a gap between two desks or 2 chairs.

Working in Groups of 2-3
How strong is the bridge without its truss structure?

SAFETY NOTE: Please have the children wear safety glasses as they test their bridges. This is sound safety practice for activities in the science classroom or lab.

- Ask each group to build STEP 1 of the K'NEX Warren Truss bridge on Page 4 of the Building Instructions booklet. Explain that they should not build STEPS 2 and 3 until they have tested the load bearing capacity of the basic beam bridge. Questions for the children to consider:
  - Where are the weak points in the bridge structure?
  - What is the maximum weight the bridge can hold before it fails?

- Record the results for each bridge on the board. Ask the children, " Do you see any information that is not consistent with the other groups in the class? Can you offer any explanations for any data that seems to be different from the other groups?"

How strong is the bridge with its truss structure?

- Ask the children to make any necessary repairs to their bridge and then continue with STEPS 2 and 3 in the Building Instructions booklet to complete the Warren Truss bridge design.

- When completed the children should re-test their structure, using the same experimental design as before.

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- Ask the children to:
  - Predict the weight their bridge might support.
  - Record and explain their findings using labelled drawings and notes.
  - Explain the effect of using triangles in their bridge structures.

Other Truss Bridges

- To investigate the other examples of truss bridges, shown on Page 5, teams of 4-6 children could build 2 variations of the Warren Truss bridge: the Howe Truss and the Baltimore Truss bridges.

- They should be encouraged to make predictions about the number of triangles built into the structure and the strength of the bridge.

- Ask each team to test their new designs and record their findings in a table such as the one shown below. They should add their results from their investigations into the Warren Truss bridge to the table.

Bridge Design	Maximum Load (Weight)	Number of triangles in structure
Warren Truss		
Howe Truss		
Baltimore Truss		

- Review the findings. Ask the question, "If you had included the K-Truss in your investigations would it have been a fair test?" Ask them to look very carefully at the Building Instructions for the K-Truss design and compare this bridge with the other three bridges shown on Pages 4 and 5.

Teachers Notes
This would not have been a fair test because the K-Truss model is a different length from the other bridge models.

Whole Class

- Discuss how the height of the beam, (its thickness), has been increased by the addition of the trusses which form a latticework of triangles. The addition of triangles has the effect of increasing the stability of the structure by adding strength and rigidity to the existing beam.

- Talk about the possible limitations of a truss bridge design when increasing the span.

Other advantages of the design: The trusses dissipate, or spread out, the compression and tension forces through the structure when a load is applied. This is important, especially as heavy loads are moved across the bridge. (This type of bridge was developed to carry heavy trains with their problem of SHOCK Load.) The open framework of the truss design allows the bridge to withstand the effects of strong winds. The wind passes though the structure and reduces its effect - known as an ENVIRONMENTAL Load.

Limitations of the design:
As the span increases the weight of the bridge will also increase until its own weight will be so large it will not be able to support itself.

Remind the children about some of the effects they observed in the previous lesson.

Extension Activity 1
Working in Groups 2-3
Ask the children to design and make plans for their own truss bridge pattern. Each group may either make their own truss bridge or ask another group to build to their plans.

Design Task
Build a truss bridge that spans 50cms. and can bear the weight of a dictionary (or other designated load)

- 2 groups combine as a bridge design team.
- They have 10 minutes planning time and a further 20 minutes to complete the building activity.
- They may use the contents of 2 K'NEX kits.
- Before constructing their bridge, ask each group to decide what form of truss they might use.

Plenary
Each group tests their bridge, while the remaining groups observe.
Ask the children to:

- Share any problems they had with their structure and describe how they overcame them.
- Suggest ways in which their designs could be improved.
- Use correct terminology and vocabulary.

Suggested Worksheet: Truss Bridges
Ask the children to identify, by name, as many truss designs as they can. Use library or Internet research to identify those that are unfamiliar.

Worksheet 2

WORKSHEET 2

TRUSS BRIDGES

Match the pictures of different truss bridge designs with their correct names. Draw a line from the name of the bridge to its matching diagram.

BALTIMORE (PRATT)

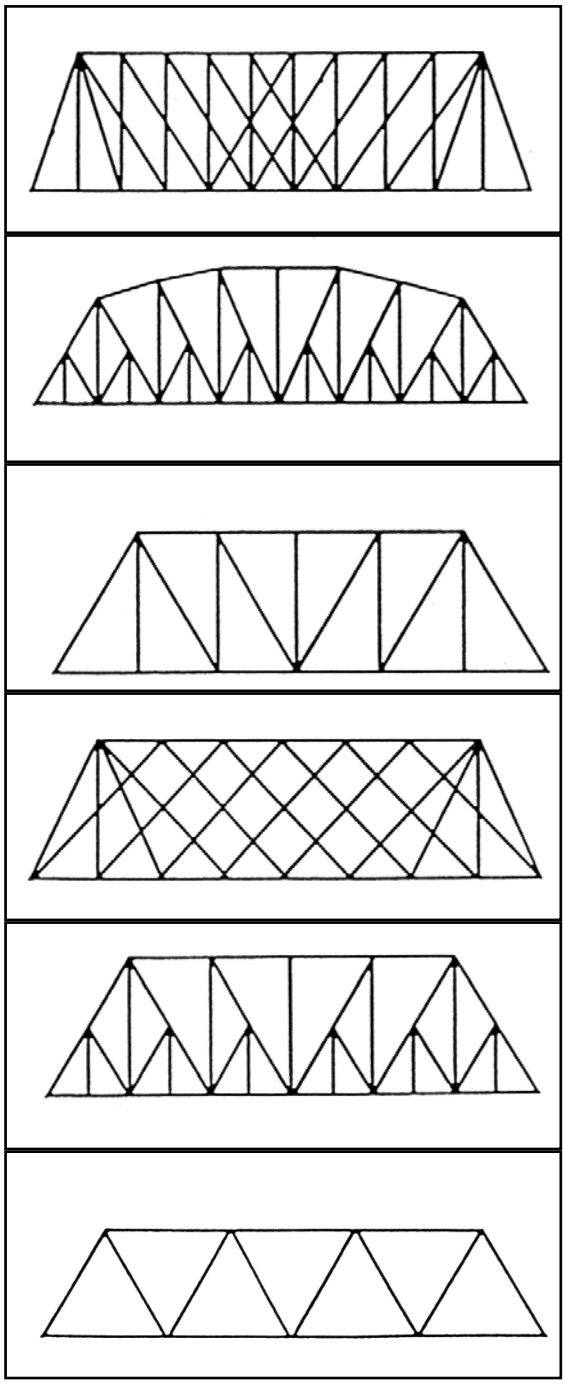
WARREN

PENNSYLVANIA (PRATT)

LATTICE

PRATT

WHIPPLE



Worksheet 2

ANSWER KEY:

WORKSHEET 2: TRUSS BRIDGES

BALTIMORE (PRATT)

WARREN

PENNSYLVANIA (PRATT)

LATTICE

PRATT

WHIPPLE