Building a Bridge Can't Be All That Difficult, Can It?

Introduction

This is a 'free building' activity in which no prior knowledge of bridge construction is assumed. Students are provided with a limited set of resources and are given a limited 'design and create' task to carry out. Their performance in this activity establishes a baseline measure of their knowledge and understanding of structural engineering concepts and it is against this that individual progress can be monitored as they work through this part of the curriculum.

Objectives

- To establish the baseline knowledge and understanding of construction technology of the students through a limited investigation.
- By discussion, to help students identify some of the key problems that must be solved by structural engineers when designing and building structures.
- To introduce and use in context the technical and scientific vocabulary associated with physical engineering.

The activity can also be used as an introduction to the design process. A limited task to be completed within a set time, with limited resources, is a reflection of real life engineering design. The students will learn not only through trial and error, but also through reflection and discussion about how well their design worked. They will also discover that designing and making structures involves considering many factors in order to successfully confront the challenges of the project.

Teams of 2-3 students are presented with 3 challenges:

- Design and build the longest bridge, without a load, that will not **fail.**
- Design and build the longest bridge capable of carrying a small **load.**
- Design and build the longest bridge that can support a small load without **sagging** or **bending.**

Materials

Each group of students will need

- 15 K'NEX Rods (any length)
- 15 K'NEX Connectors (any type)
- K'NEX Real Bridge Building instructions booklet (Page 2)
- 50g and 100g weights/slotted masses
- Rulers

Vocabulary

beam, load, dead load, live load, span, bending, sagging, rigid, fail, failure, strength, design specifications, structure

Challenge I

- Using only the specified materials, students design and make the longest bridge. It does not have to support a load, but it must not fail.
- The bridge does not have to be a free-standing structure, but can simply span the gap between two desks or two chairs.

Skill Builder 1 Teacher's Notes

SECTION I

- Students can use **a maximum of 15 K'NEX Rods** (of any length) and **15 Connectors** (of any type) in their bridge construction.
- Maximum thinking and building time allowed: 20 minutes.

Challenges II and III

- Allow a maximum of 15 minutes for each challenge.
  - II. Using only the specified materials, students design and make the longest bridge that can span a gap and support a 100g load at its mid-point?
  - III. Using only the specified materials, students design and make the longest bridge that can support a 50g load without sagging or bending?

Question:
Of the three bridges each group has made, which is the strongest?

Process

Whole Class

- Allow a few minutes for students to select their construction materials from the K'NEX Real Bridge Building set.
- Before starting their 'design and create' challenge, students may be introduced to the K'NEX building tips shown on Page 2 of the Real Bridge Building instructions booklets.

Working in Groups 2-3

- Students should be encouraged to spend a few minutes discussing how they might tackle the challenge before starting to build.
- They should be asked to record their ideas and observations. They may want to address some of the following areas:
  - What ideas were rejected/accepted and the reasons for their decisions?
  - How their bridge performed against their expectations/the design specification.
  - What changes they made to the bridge structure during construction to make it meet the design specification.

Given that the students only have a small number of components to work with, the most likely bridge constructed will be a **simple beam bridge.**

In attempting to make a long bridge they should find that the beam will soon start to sag under its own weight **(dead load)** and a bridge more than 7 or 8 of the longer K'NEX rods in length may be so weak as to break under its own weight.
Students should also discover:

- In order to carry a load **(live load)** a bridge must be **structurally strong** enough to support both the dead load and the live load.
- Long **span** beam bridges have a lower load bearing ability when compared to short span beam bridges made from the same pieces and to the same design.

K'NEX structures, along with many other structures, are likely to fail where structural components are joined together. It is at the joints or connections that stress forces focus. Any weakness here will result in structural failure. Careful observation of the connections in their K'NEX model will show how they may be forced apart by bending forces.

Assessment

- After the construction and testing, students should provide a short report of approximately 100 words on the strengths and weaknesses of each of their 3 bridges.

Whole Class

- Discuss the merits and issues raised by the success and failure of each group's design.

- What did the students learn about bridge structure and function? How and where did their structures fail?

- Why is it important for the beam to remain **rigid** when subjected to a load?

- What changes might they make to strengthen their design so that the beam will remain rigid over a longer distance, even when a load passes over it?

- How do structural engineers solve the problem of maintaining a stiff bridge span structure over long distances? Refer the students to the photographs in the K'NEX Real Bridge Building instruction booklets or visit **www.brantacan.co.uk.**

- Discuss how most people take it for granted that a bridge will not sag when they drive or walk across it. Would the students feel safe using a bridge that sagged? Automobiles and trucks would also find it difficult to use such a bridge. Additionally, it is not only the live and dead loads that must be taken into consideration but also **environmental loads** such as wind, snow, ice and currents of water.

- You may also wish to introduce the importance of the choice of materials in bridge design. Explain how the ability of engineers to design and construct longer and longer bridges only advanced with the discovery and use of new technologies and materials. Wood and stone were superseded by cast iron, wrought iron and then steel. Today many bridges are constructed using reinforced concrete and/or a combination of different materials. Understanding the physical properties of materials and how they behave when subjected to different types of forces is essential knowledge for any successful structural engineer.

Reference Material for Upper Grade Levels

- ***Reader # 4: Stress, Strain, Stiffness and Young's Modulus.***

Extension Activities

To extend the activity you may find it useful for students to investigate some famous bridge disasters such as the Tacoma Narrows Bridge in 1940; the Quebec Bridge 1907, 1916 and the Tay Railway Bridge 1897. Film footage and photographs of the Tacoma Narrows Bridge failure is available on a number of web sites.

http://www.lib.washington.edu/specialcoll/tnb/: Contains photographs of the Tacoma Narrows Bridge under construction and after the collapse.

http://www.ketchum.org/bridgecollapse.html: Provides references to a number of bridge collapses, video footage of the Tacoma Narrows Bridge and graphics of the Tay Railway Bridge disaster.

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Consider This

A bridge is a structure used to cross some form of barrier, making it easier to get from one place to another without having to make long detours.

- What are the key features you think a bridge should have? Make a short list in your workbook or journal.

- What should a bridge not do when you travel across it? Keep these features in mind when you make your own bridges.

In this activity your team is challenged to make 3 simple beam bridges from K'NEX materials and then investigate how they behave when **forces** are applied to them. *Think of a beam as a heavy board supported at either end and used to span a gap.*

Materials

- 15 K'NEX Rods of any length from the Real Bridge Building set
- 15 K'NEX Connectors of any color from the Real Bridge Building set
- 50g and 100g weights or slotted masses
- Ruler

Safety Note: Please wear safety glasses as you undertake these investigations.

Challenge I

I. What is the longest bridge you can make with the materials provided, that does not break (fail)?

- This bridge does not have to support a load.
- The bridge does not have to be a freestanding structure but can simply span the gap between two desks or two chairs.
- Your team may use a maximum of 15 Rods and 15 Connectors for the bridge.
- You have 20 minutes for thinking, building and recording.
- Measurements required:
  1. The maximum gap your bridge spans.
  2. The maximum gap your bridge spans without sagging or bending.

What To Do?

1. Once your team has selected the Rods and Connectors, spend a few minutes discussing how you are going to tackle the task before starting to build. Some planning before taking action usually helps. You should keep a record of what ideas were rejected, or accepted, and why.

2. If you are unfamiliar with how K'NEX components fit together, ask your teacher if you may have a look at Page 2 of the Real Bridge Building Instructions Booklets.

3. Once you have completed your bridge, take the required measurements.

Skill Builder 1
Student Inquiry Sheet

SECTION I

Your Observations

Use drawings and written notes to record your ideas and observations in your notebooks or journals. You may want to include responses to the following questions:

- How does your bridge perform against the expectations you listed at the beginning of this activity?
- Where does the bridge bend the most?
- Why would you not use your long bridge design to cross a barrier?
- How might you strengthen (reinforce) your bridge so it can carry a 100g load at its mid-point?

Challenges II and III

II. What is the longest bridge you can build that can span a gap and carry a 100g load at its mid-point?
Your team may use a maximum of 15 Rods and 15 Connectors for the bridge.

III. What is the longest bridge you can make that will support a 50g load without sagging or bending?
Your team may use a maximum of 15 Rods and 15 Connectors for the bridge.

- Maximum time allowed: 15 minutes for each challenge.
- Measurement required for Challenge II: The maximum gap your bridge spans.
- Measurement required for Challenge III: The maximum gap your bridge spans without sagging or bending.

Your Observations

Use drawings and written notes to record your ideas and observations in your notebooks or journals.

Think about what you have learned about beam bridges:

- Do long beams behave the same way as short beams?
- How and where did your structures fail?
- Why is it important for your beam bridge to remain **rigid** when carrying a load?
- What changes might you might make to strengthen your design so that the beam will remain rigid over a longer distance, even when a load passes over it?
- How do structural engineers solve the problem of keeping the bridge span structure rigid over long distances?

Reporting Back

Using written text and drawings, produce a short report of no more than 100 words on the **strengths** and **weaknesses** of each of the bridges you made, using the correct technical vocabulary when describing your observations.

- What ideas were rejected or accepted and why?
- How did your bridge perform against your expectations/the design specification?
- What changes did you make to the bridge structure during construction so that it could meet the new design specifications?

Vocabulary

beam, load, dead load, live load, span, bending, sagging, rigid, fail, failure, strength, design specifications, structure