BRIDGE BUILDERS TEACHER PACK

Resources pack to support the delivery of KS3 and KS4 Science, Mathematics, and Design and Technology using Expedition Workshed

think up

DEVELOPED IN ASSOCIATION WITH THE INSTITUTION OF STRUCTURAL ENGINEERS EDUCATIONAL TRUST

INTRODUCTION

Bridge building is one of the clearest and most eye-catching examples of the work that engineers do. The development of bridge design maps closely to technological, economic and social development and the development of interconnected societies; yet even as long ago as Roman times, engineers have been capable of building bridges at awe-inspiring scales.

The bridge building theme gives teachers the opportunity to teach about the application of Science, Mathematics and Design and Technology. This teacher pack gives guidance on how to use the resources on Expedition Workshed to base lessons and learning activities around the bridge building theme.The activities are designed to be exciting and memorable, allowing students to use Workshed to access a range of interactive resources.

The resource pack contains two core activities, together with suggestions for complimentary activities that can be either used in isolation or in support of the core activities.

Construction of the Stonecutters Bridge, Hong Kong.

The pack provides a summary of the possible learning outcomes associated with Key Stage 3 and Key Stage 4 Science, Mathematics and Design and Technology. In addition, the Staffroom area of Expedition Workshed provides links to specific lesson plans developed by other schools and organisations.

This resource pack has been developed by education design company Think Up in association with the IStructE Educational Trust. The content of the pack includes:

LEARNING OPPORTUNITIES

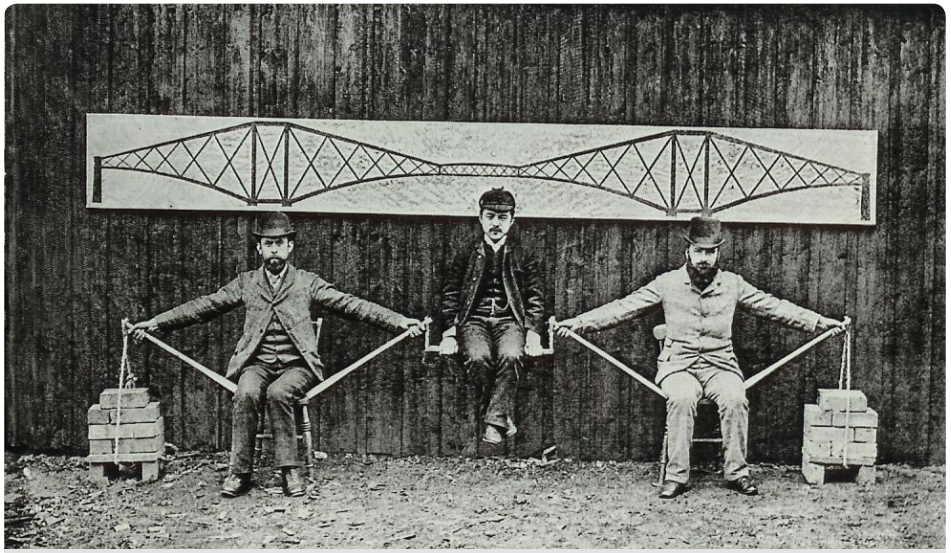
This resource pack is supports teaching of science maths and design and technology at Key Stage 3 and 4 of the National Curriculum for England and Wales. The pack offers teachers real-life examples as a basis for teaching secondary curriculum subjects, helping their students become successful learners
and excellent communicators.

The workshops and activities are designed to engage learners at many levels, linking theoretical concepts and high-quality resources with practical experience. They allow students to develop an understanding of what engineers do, and encourage them to research and experiment, and discuss and develop ideas.

Science

The activities in this teacher pack offer students the opportunity to:

- Link direct practical experience with scientific ideas.
- Use experimentation and modeling to develop explanations and encourage critical and creative thought.
- Explore how technological developments can change the way people live.
- Use the internet as an aspect of scientific research.
- Use digital photography, video or podcasting as alternatives to text-based approaches to communicate scientific information.
- Understand how forces can affect the shape of materials.
- Understand the property and use of materials.
- Provide a qualitative description of an experiment.
- Learn how the properties of a material determine its uses.
- Understand the role of the scientific community in validating knowledge.



Human model of a cantilever bridge

Mathematics

The activities in this teacher pack offer students the opportunity to:

- Understand how mathematics is used as a tool to solve problems in engineering.
- Use applications of trig, shape, area, geometry.
- Identify limitations of the scope of model.
- Understand forces.
- Examine a situation systematically and work out how to break it down.
- Solve problems in small groups.
- Understand how mathematics is used in the real world.

LEARNING OPPORTUNITIES

Design and Technology

The activities in this teacher pack offer students the opportunity to:

- Explore how products have been designed and built in the past, how they are currently designed, and how they may develop in the future.
- Apply knowledge of materials to produce practical solutions.
- Explore experimenting with ideas, materials, technologies and techniques.
- Explore critically the impact of design decisions.
- Respond creatively to a brief.
- Reflect critically when evaluating and modifying their ideas and proposals to improve products throughout their design and development.
- Use their understanding of others' designing to inform their own.
- The behaviour of structural elements in a variety of materials, including understanding loads and other forces, resistance to loads without deforming, and the connection and transfer of forces within a structure.
- Make links between design and technology and maths and science.

Personal, Learning and Thinking Skills

The activities in this teacher pack offer students the opportunity to:

- Undertake independent enquiry and carry out their own research.
- Explore issues from different perspectives.
- Generate ideas and show creative thinking.
- Analyse and evaluate information, judging its relevance and value.
- Support conclusions, using reasoned arguments and evidence.
- Work as a team towards a common goal, resolving issues to reach agreed outcomes.
- Develop their self-management skills.
- Show initiative and perseverance.
- Organise their time.
- Test alternatives and new solutions.
- Evaluate their learning; reviewing progress and inviting feedback.
- Provide feedback to others.
- Evaluate their experiences.
- Communicate their learning.

Infinity Bridge, Stockton-On-Tees

SUMMARY OF CORE ACTIVITIES

The core activities in this section provide opportunities for cross-curricular working in an exciting team work context. Through asking students to examine and take on the role of bridge designers, they are given the opportunity to learn about a range of subjects.

Full briefing notes for facilitators and students are given at the back of this pack, and are available for download from Staffroom.

Bridge Building Competition

In this exciting group work activity, teams of students compete to build and test to destruction a bridge built from paper and string. The student brief is to design and build a 1:100 scale model of a footbridge designed to span 120m. Teams must test their bridge by hanging weights from the centre of the span: the team that builds the bridge that can support the greatest weight for the least use of materials is the winner.

Putting students in a structural engineer's boots, this workshop gives student the opportunity to:

- Respond creatively to a brief.
- Understand forces and their effects.
- Consider appropriate use of materials.
- Experiment with design and adapt their designs according to observations.

The Materials Fact File and Bridges Fact File available for download from Staffroom together with the other resources on Workshed, can be used to provide students with background information for both core activities.

The Bridge Building Competition requires a minimum of 1.5 hours to complete in a single session, but the workshop can be extended or broken up in order to build in additional activities, for example:

- Producing a photo diary or film of the design and testing of the bridge.
- Designing an experiment to predict, test and explain how the bridge will fail under testing.
- Producing a technical drawing of their bridge, using principles of geometry to add dimensions to their drawing.

Bridge Investigation Project

In this project students carry out a research project about a particular bridge, using a range of different source materials, and present the findings of their research as either a photo slideshow, a short movie, or pod cast.

The student brief suggests three possible research topics:

1. Choose one of the main types of bridge and tell the history of its design.
2. Choose one of the main types of bridge and describe how the structure transfers loads from the middle of the span to the supports.
3. Tell the story of a local bridge: when was it built; who built it and why; how is this bridge of benefit to the local community?

This activity can be carried out by individuals or by groups. The activity can be run as a competition in which the winners are the students judged to have produced the best presentation, as judged either by the teacher or their fellow students.

COMPLEMENTARY ACTIVITIES

The following activities can either be used in isolation or used to complement the delivery of the core activities.

Forces on bridges

Bridges can offer a very clear picture of how forces are transferred through a structure. Different types of structure transfer forces in very different ways. The Bridge Building Competition gives students a very practical feel for how forces are transferred through a structure, and the effect on the structural elements through which these forces are transferred.

Activity ideas

Discussion point – what forces act on bridges?

Ask students to identify the main forces acting on a number of bridges. Use the Bridges Fact File for examples of bridges to discuss.

Students should be able to distinguish:

- Dead loads – the weight of the structure itself and any other load on the structure which is not removed. These all act in downwards.
- Live loads – the weight of the bridge users (traffic, pedestrians, trains); loads due to the weather, most notably wind load which tends to act sideways.
- Seismic loads – especially if the bridge is in a seismically active area.

Dynamic loading

These two videos show famous examples of the effect of dynamic loading on a bridges:

- The Great Millennium Gamble
- Tacoma Narrows

Forces in different types of bridge

By using physical models, students can identify how the different types of bridge structure transfer the load from the middle of a bridge's span to the supports.

When carrying out the Bridge Building Competition, students should be able to identify which elements go into compression, which elements go into tension when the structure is loaded.

Equal and opposite reactions

Use the example of a simple beam to demonstrate how the load on a bridge is equal and opposite to the loads in the reactions.

Using the simply supported beam Push-Me-Pull-Me model, you can use the mouse to apply a load to the centre of a bridge, and move the position of the load on the beam to see how it affects the loading in the supports.

Using the two-span continuous beam Push-Me-Pull-Me, you can demonstrate how a load on a bridge could theoretically cause the structure to pull up on the bridge support.

For a more in-depth practical experiment using top-pan balances to demonstrate equal and opposite reactions in bridge supports, refer to the Bridge Design teaching materials developed by the University of Cambridge.

COMPLEMENTARY ACTIVITIES

Understanding materials

Bridges construction can be used as the basis of a discussion about material properties. The downloadable Materials Fact File gives examples of different construction materials, their history and their application in bridges. Use this fact file to provide additional background information for the Bridge Building Competition.

Activity ideas

Brittle vs ductile behaviour

The Stuff Failure section in Workshed shows spectacular footage of brittle failure in glass and concrete, which can be compared with ductile failure of steel.

Appropriate use of materials

Based on the information in the Materials Fact File, ask students to figure out why particular materials were chosen for a number of iconic bridge structures. Explore why bridges have been designed using different materials in the past, currently and in the future. Use the downloadable Bridges Fact File as visual stimuli or refer to the following bridges on Workshed:

- Millennium Bridge
- Britannia Bridge

As part of the Bridge Building Competition, encourage students to work out materials they are simulating with their string and paper models.

Design Decisions lesson plan

This lesson plan is part of a suite of activities designed by Cambridge University around the theme of bridge design.

The impact of bridge engineers on society

Advances in bridge engineering have allowed enormous transport networks to be developed. The early pioneers of bridge design, such as Brunel and Telford based much of their designs on trial and error. But even using powerful computers, modern day bridge engineers still encounter difficulties, as in the case of the Millennium Bridge.

Activity ideas

Film time

The following videos tell the story of two Victorian engineers and one 20th Century bridge engineer:

Isambard Kingdom Brunel
George Stephenson
Chris Wise

Links to other useful bridge websites

- Brantacan.co.uk
- Tallest bridges in the world
- Longest bridges in the world
- Top ten most amazing bridges
- Building Big Bridges Lab
- Discover Engineering

BRIDGE BUILDING COMPETITION

A group design, build and test competition using Expedition Workshed

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BRIDGE BUILDING COMPETITION

Facilitator notes

Introduction

In this exciting group work activity, teams of students compete to build and test to destruction a bridge built from paper and string.

The student brief is to design and build a 1:100 scale model of a footbridge designed to span 120m. Teams must test their bridge by hanging weights from the centre of the span: the team that builds the bridge that can support the greatest weight for the least use of materials is the winner.

Putting students in a structural engineer's boots, this workshop gives students the opportunity to:

- Respond creatively to a brief.
- Understand forces and their effects.
- Consider appropriate use of materials.
- Experiment with design and adapt their designs according to observations.

The Bridge Building Competition requires a minimum of 1.5 hours to complete in a single session, but the workshop can be extended or broken up in order to build in additional tasks, as described in the 'Other activities' section below.

Setting up the space

This workshop is ideally carried out in a large classroom or hall. The students are asked to build a bridge that spans 1.2m. Building the bridge between two desks separated by 1.2m is a good way to simulate this gap.

Students will need desk space in order to assemble the components of their bridge. The final testing of their bridge could either take place at their work station, or at a specially designated testing space at the front of the class.

Material requirements
A4 paper, sticky tape, scissors and string. If you limit the quantity of materials that students have access to from the start then it is easier to measure material usage, and to encourage them to think more creatively about material use. You will require a set of weights for bridge testing (ideally at 100g increments).

Briefing the students

You can brief the students by providing them with a copy of the student briefing sheet. They can access the Bridges Fact File and Materials Fact File in Staffroom which provide links to online interactive resources.

Testing and judging

The aim of the testing process is to test the students' structures to destruction, adding to the excitement of the activity. Test the bridges by adding increasing numbers of weights to the middle of the span.

The students are told that their bridges will be tested according to four criteria:

1. Maximum weight supported before collapse.
2. Efficient use of materials.
3. Elegance of design.
4. Their ability to describe how the materials are transferring the forces in the bridge.

BRIDGE BUILDING COMPETITION

It is up to you to decide how to weight each of these factors. You could simply rank the each bridge for each factor (higher rank, greater score), and add up the scores to determine the winner.

Other activities

In addition to the basic requirements of the student brief, there are many ways to add to this activity to meet particular curriculum needs. Below are some suggestions.

Producing a drawing

Ask students to produce an accurate drawing of their final bridge structure, showing the dimensions at full scale in order for students to practice converting from one scale to another.
Ask students to produce an artist's impression of the bridge that could be used as part of the planning approval process with the local council.

Experiment

Ask students to predict how their bridge will fail, and then to design and run an experiment to monitor the failure of their bridge. They could for example measure the vertical displacement of the central span or the horizontal displacement of any supporting towers as they add weight to the structure. Students can plot their results and try to explain their findings.

Design and test

Given more time, teams of students would have the opportunity to test a number of different bridge designs before deciding on and building their final model. As part of this process, students could set themselves a design specification and evaluate each design according to this specification, and then evaluate how their final design performed under final testing.

Communicate

Ask students to make a presentation about their bridge to their peers. You could ask them to describe why they chose the design they did, and to explain how the bridge ultimately failed.

Ask students to produce a multi-media presentation about their bridge (for example, a photo montage or short video). See the 'Bridge Case Study Multi-media Competition' for additional guidance on shooting video and taking photos.

BRIDGE BUILDING COMPETITION

Student brief

Intro

Bridge building is one of the clearest and most eye-catching examples of the work that engineers do. The development of bridge design maps closely to technological, economic and social development and the development of interconnected societies; yet even as long ago as Roman times, engineers have been capable of building bridges at awe-inspiring scales.

The aim of this competition is to put you into a structural engineer's boots and to work in a team to develop and test a design for a bridge to span 120m.

In addition to the brief outlined here, you supervisor may ask you to carry out additional activities along the way.

Brief

Work in teams to design a bridge that spans 120 metres at 1:100 scale. In the time available you must build the lightest, strongest bridge you can, using only A4 paper, sticky tape and string.

The bridge must have a single span of 1.2 metres, with no additional supports in the middle.

The bridge may be attached to the supports, and to the 'ground' anywhere behind the supports (if for example you are building a suspension or cable-stayed bridge).

The bridge must be built from the sides – i.e: no one standing in the water!

Testing and judging

Your bridge will be tested to destruction by hanging more and more weights from the centre of the span until it collapses.

The winning bridge will be decided according to four criteria:

1. Maximum weight supported before collapse
2. Efficient use of materials
3. Elegance of design
4. Your ability to describe how the materials are transferring the forces in the bridge

Starting points

- What type of bridge? Use the Bridges Fact File.
- What materials do you have at your disposal?
- How will you build the bridge, given that you are not allowed to 'stand in the water'.
- Organise your team.
- One part of your team could research bridge types whilst the other could research materials.
- Once you have a design for your bridge, you may need to form your own production line in order to construct all the elements necessary for the bridge.
- Who in the team is going to assemble the final structure?

BRIDGE INVESTIGATION PROJECT

A multi-media research and presentation activity using Expedition Workshed

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BRIDGE INVESTIGATION PROJECT

Facilitator notes

Introduction

The aim of this project is to give students the opportunity to research the work of engineers to find engaging ways to communicate engineering principles.

Students are asked to conduct a research project according to one of three themes, and then find a creative way to communicate their findings, for example by producing a video, photo montage or podcast.

The workshop combines developing research, independent working and communication skills. See the student briefing notes for more information on the project themes.

Once the students have presented their projects, there is the opportunity for their peers to provide feedback, and to vote for their preferred project.

This research project can be carried out by individuals or in groups, and over a timeframe that suits the time available.

Space and material requirements
Recording equipment, etc.
Space to show the final presentation.

Briefing the students

The student briefing sheets provide all the information they need to get started on the project. A good starting point may be to use the Bridges Fact File in order to access materials on the Workshed website.

Other activities

In addition to the basic requirements of the student brief, there are many ways to add to this activity to meet particular curriculum needs. Below are some suggestions.

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BRIDGE INVESTIGATION PROJECT

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The aim of this project is to give you the opportunity to research the work of engineers to find engaging ways to communicate engineering principles.

Brief

Your brief is to carry out a research project about a particular bridge you have chosen, using a range of different source materials, and to present the findings of your research as either a photo slideshow, a short movie, or podcast.

You must select one of the following three possible research themes:

1. Choose one of the main types of bridge from the Bridges Fact File and tell the history of its design.
2. Choose one of the main types of bridge from the Bridges Fact File and describe how the structure transfers loads from the middle of the span to the supports.
3. Tell the story of a local bridge: when was it built; who built it and why; how is this bridge of benefit to the local community?

You must then find a creative way to present the findings of your project, for example by:

- Making a short film
- Producing a podcast
- Creating a photo montage
- Designing a poster

This activity can be completed either as individuals or in groups. You peers will give you feedback on your project, and the best project will be chosen by popular vote.

Starting points for your research

Once you have chosen your research theme, you can use the materials on Expedition Workshed to begin your research. In particular you will find the Bridges Fact File a good starting point.

If you are researching the behaviour of a particular type of bridge then you should consider building a scale model of that type of bridge. You could then use this model to conduct a series of experiments on your bridge.

Starting points for presenting your work

Telling a story

A good story needs to have a beginning, middle and end, and it needs focus. You need to think of your audience: what will interest them? If you plan on visiting a local bridge you should start thinking about your story before you leave.

Ask yourself what it is you're most interested in finding out about the bridge you have chosen.

Taking photographs

The camera sees differently to the eye so always check the viewfinder or screen. Good photos are about looking, so keep your eyes open and keep recording what you see.

- *Framing* – look at the subject in the frame and make it interesting. Don't leave loads of space above the head or put something right in the middle of the picture. Think about shapes and angles.
- *Take lots of pictures* – then delete the rubbish ones later.
- *Background* – check the background is relevant or make it neutral.
- *Get up early* – the light is always best first thing. Sunset is good too but tends to be more hazy.
- *Contrast* – dark items against a light background will not look good. If possible use flash to fill, particularly on a bright sunny day.
- *Focus* – check the camera is focusing on what you want it to focus on.
- *Avoid using flash at night* – it usually looks awful. Slow shutter speed shots may be blurry but can be very atmospheric.
- *Keep it steady* – use a tripod or a stable surface to lean against or hold your breath whenever you can. This will also help you frame better.
- *Crop and edit pictures before presenting them* – choose the pictures you present carefully.

Tips for shooting video

When recording video, all the same rules apply as for still photography – except now, you also have to think about movement and the edit.

Audio is the biggest problem with small cameras, so pay careful attention to what the camera is recording. If you can't see the source of a sound in the picture it shouldn't be there. In particular, watch out for planes police sirens or a noisy vehicle passing. Short sharp sounds are easy to get rid of but gradual build up of noise is impossible, particularly when you start to edit. If something does come up, stop and start again once it's gone.

Here's a checklist for good recording:

- *Keep the mic close* – too far and it will be off-mic and inaudible.
- *Switch off mobile phones* – it's not just the sound of ringing, even on silent, the signal creates interference (a clicking) on the sound track
- *Get more material than you think you need* – particularly of the environment. Use the camera to set the scene (wide shot), show the detail (close ups) and tell a story (following the action). The more of these purely visual shots you get the easier it will be edit together an entertaining piece later.
- *Keep it still or move with a purpose* – moving the camera is fine just be aware of what the destination is and stop there for several seconds before moving on.
- *Framing* – allow a subject to enter or leave the frame rather than following them around. This gives you a natural editing point later.
- *Shoot lots of varied material* – the more images you have the more flexibility you'll have when editing.

Combining photos with video

Mixing photographs with audio usually works very well. Don't be afraid to mix media: mixing photographs with audio works very well. Use written titles or create graphics over photos and video so the audience knows what they're looking at.

Editing your material

Begin with the end. Think first about what you want to leave your audience with and work back from that. Create smaller stories or sequences first. Put those together as stand-alone pieces, then link them up in an order that works and leads into the final thought.

Do the beginning last – as this is the hardest thing to do well. Set the scene for the story you now know you're going to tell.