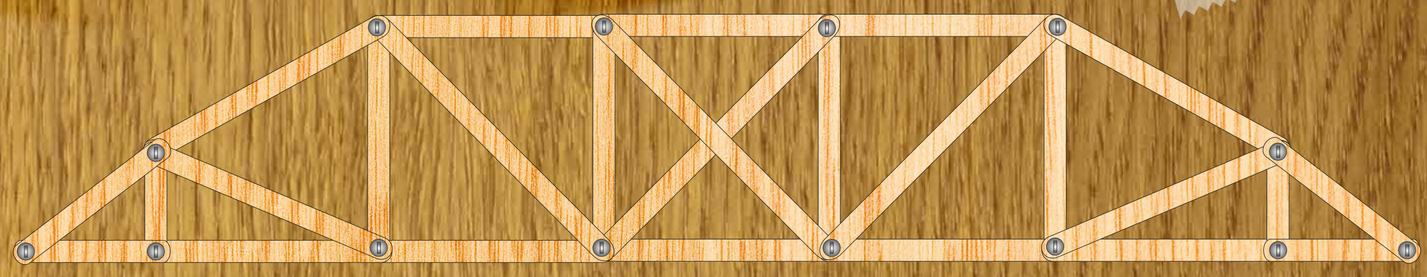
Bridge Design Challenge

National 4&5 STEM Project



SQA Outcomes

Learners will:

1. Investigate engineered objects by:
   - Describing how engineered objects work.
2. Investigate engineering challenges and relate these to key engineering concepts by:
   - Describing how different branches of engineering contribute to solving an engineering challenge.
   - Modelling a solution to an engineering challenge.
3. Describe some aspects of the impact of engineering by:
   - Describing the social and economic impacts of engineering.
   - Describing examples of the environmental impacts of engineering.
   - Describing ways in which engineering solutions contribute to tackling climate change.

(Engineering Science: Engineering Contexts & Challenges)

4. Investigate a range of mechanical and pneumatic systems by:
   - Describing or producing diagrams of simple force systems/a range of structures.
5. Develop mechanical or pneumatic solutions to solve problems by:
   - Identifying key aspects of a problem.
   - Applying basic knowledge/knowledge and understanding of structures, pneumatics and/or mechanical drive systems.
   - Simulating/Designing, and simulating or building, mechanical or pneumatic systems.
   - Testing/Testing and evaluating solutions against a specification.

(Engineering Science: Mechanisms & Structures)

6. Apply skills of scientific inquiry and draw on knowledge and understanding of Forces to carry out an experiment/practical investigation by:
   - Planning an experiment/practical investigation.
   - Following procedures safely.
   - Making and recording observations/measurements correctly.
   - Presenting results in an appropriate format.
   - Drawing valid conclusions.
   - Evaluating experimental procedures.

(Physics: Dynamics & Space)

7. Use mathematical operational skills linked to expressions and formulae by:
   - Applying algebraic skills to manipulate expressions and working with formulae.
8. Use mathematical reasoning skills linked to expressions and formulae by:
   - Interpreting a situation where mathematics can be used and identifying a valid strategy.
   - Explaining a solution and/or relating it to context.

(Mathematics: Expressions & Formulae)

9. Create 2D promotional graphic layouts by:
   - Producing single-page displays that have visual impact and incorporate recognised desktop publishing techniques.

(Graphic Communication: 2D Graphic Communication)

Big Task

The Forestry Commission Scotland have approached you to design a new footbridge to cross a small river which intersects one of their walking trails. It will replace an old crossing which was destroyed during last year's winter storms. The bridge is to be made of British-grown oak wood and must be strong enough to withstand regular use from the walkers, cyclists and horse riders using the trail. The positioning and design of the bridge must take into consideration the geographical features of the site. You will work in small groups to explore and investigate basic bridge structures then individually to design, model and test solutions to this design challenge. The winning design will be the most economical, aesthetically pleasing and well-presented solution which also withstands the load testing activity.

Case Study Task

Investigation of Braklinn Falls wooden footbridge structure.

Small Tasks

- Wood: A Sustainable & Strong Construction Material (Lesson 1)
- Introduction to Basic Bridge Structures (Lesson 2)
- Investigating Triangulation (Lesson 2)
- Calculating Load (Lesson 3)
- Exploring Tension and Compression (Lesson 3)

Lesson Outline

Lesson 1: Trip to Queen Elizabeth Forest Park
Achray Forest (David Marshall Lodge Visitor Centre):
- Introduction the design challenge brief.
- Presentation by the Forestry Commission Scotland on the properties of wood and what makes it a good construction material, explanation of carbon capture and storage in wood, the effects of climate change linked to storm damage and the sustainability of using British grown wood from managed forests.
- Introduction to The Circular Economy by the Ellen MacArthur Foundation.
- Presentation from Strong Bridges Ltd. describing design & manufacture processes of the Bracklinn Falls footbridge.

Callander Crags Woodland:
- Walk to and group investigation of the structure of the wooden footbridge at Bracklinn Falls. Photography & annotated sketching of bridge features.

(Whole Day: 8 Hours)

Lesson 2: Introduction to Bridge Structures and Triangulation
- Introduction to the three basic types of bridge structure: Beam, Arch & Suspension.
- Group investigation into the use of triangulation to create frames and strengthen structures using paper straws and fasteners, max. 4 pupils per group.

(2 Hours)

Lesson 3: Calculating Load
- Introduction to the formulae and methods for calculating UDL on a bridge structure.
- Calculation of load for design brief.
- Exploration of tension and compression within a structure.

(2 Hours)

Lesson 4: Bridge Design
- Introduction of scenario including diagram showing geographical features/topography.
- Formation of initial bridge design ideas.
- Use of West Point Bridge Designer to simulate, test and develop designs.
- Use of bridge costing worksheet to cost design solutions.

(2 Hours)

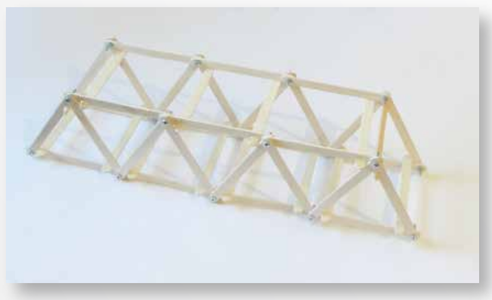
Lesson 5: Bridge Building
- Manufacture of lollipop-stick bridges from developed designs using nylon thread, nuts, bolts and hot glue guns for connections.
- Recording of models design & structure using photography and creation of a client presentation.

(2 Hours)

Lesson 6: Testing & Evaluation
- Testing of model bridge designs using load calculated in lesson 3.
- Recording of results, at what weight did unsuccessful designs break?
- Presentation of designs to client and marking.
- Prize-giving to winning designer.
- Evaluation of successful & unsuccessful designs.

(2 Hours)

Wooden Footbridge at Bracklinn Falls
http://www.panoramio.com/photo/50477901



Example Bridge Model

Learning Aims

- To develop learner s knowledge of wood and the properties that make it a strong and sustainable construction material.
- To investigate different types of bridge structure and experiment with the use of triangulation to strengthen structures.
- To introduce the technique for calculating load and the concept of tension & compression within structures.
- To introduce the use of software as an aid for design testing and development.
- To develop investigation, problem solving, creativity & higher order thinking skills through a design challenge.
- To develop learner's numeracy & enterprise skills through costing of the final design.
- To develop communication, discussion & interpersonal skills through group work tasks.
- To develop record-gathering skills throughout a project.
- To develop testing and evaluation skills through the investigation of successful and unsuccessful designs with relation to the design brief.

Learners Design Decisions

- Structures used in bridge design.
- Connections used in design - glue gun and/or nuts & bolts.
- Number of lollipop-sticks used in design.

Skills for Learning, Skills for Life & Skills for Work

Literacy
- Communicating knowledge, understanding and ideas through writing, listening and talking during the design challenge.

Numeracy
- Number Processes: Using formulae to carry out force calculations, understanding and using the results to make design decisions.
- Money, Time & Measurement: Using and understanding money, time and measurement to solve design problems using relevant units and suitable instruments.
- Information Handling: Interpreting data from charts and diagrams and using it to make design decisions.

Health & Wellbeing
- Personal Learning: Actively engaged in learning, thinking constructively and learning from experience during simulation structure testing.
- Relationships: Building social and working relationships and practicing interpersonal skills through group work tasks.

Employability, Enterprise and Citizenship
- Information & Communication Technology (ICT): Using simulation software to make informed design decisions.
- Working with Others: Practicing co-operative working, negotiation and discussion skills during group work tasks.
- Enterprise: Being creative, flexible and resourceful, understanding how to use initiative during the design challenge.
- Citizenship: Having concern for the environment, being aware of global sustainability issues such as climate change, understanding and acting responsibly in regard to these.

Thinking Skills
- Remembering: Remembering formulae for simple calculations and explaining the features of different bridge structures.
- Understanding: Using knowledge of structures to form solutions for design problems.
- Applying: Using existing information to plan, organise and complete the design challenge task.
- Analysing & Evaluating: Reviewing and considering different design solutions.
- Creating: Designing and making an innovative and new solution to the initial design problem.

Rationale Summary

This unit of work has been designed as a partnership project with learners and teachers working in partnership with the Forestry Commission Scotland and the Ellen MacArthur Foundation. The case study task included in this unit also provides learners with an outdoor learning opportunity providing relevance and depth to the curriculum (Learning and Teaching Scotland, 2010: 5). The real-world context, use of partnership working to provide live clients for the design challenge and problem based nature of this unit create an authentic context which should both engage and motivate learners, providing challenge and enjoyment in line with the Principles of Curriculum Design (The Scottish Government, 2008: 41).

The big task associated with this unit of work contains an element of competition with each learners design solution being tested and evaluated by the client ending in one winning design proposal. The inclusion of this competitive element can be seen as a further motivator for learner engagement and also provides an opportunity for personal achievement, listed as one of the purposes of senior phase education (The Scottish Government, 2008: 40).

The underlying focus of this unit of work is sustainability. The unit aims to inform learners about the issue of climate change and ways in which CO2 emissions can be reduced through carbon capture and the use of wood in construction from local, responsibly managed forests instead of other materials such as metals and plastics. The knowledge and understanding of issues relating to sustainability developed in this unit will assist learners in becoming responsible citizens who are able to evaluate environmental, scientific and technological issues , develop informed, ethical views of complex issues and make informed choices and decisions (The Scottish Government, 2008: 22).

This unit of work has been developed as an interdisciplinary STEM project based on National 4 and 5 Engineering Science and including elements of Mathematics, Physics and Graphical Communication. Interdisciplinary projects allow learners to make connections between different subject areas and provide the opportunity to create inspiring contexts that provide relevant, challenging and enjoyable learning experiences (The Scottish Government, 2008: 21). It is my intention that different sections of this unit will be taught by staff from each of these subjects, providing expertise in each area and making the links between each subject explicit to learners and. It is also intended that the interdisciplinary, STEM setting of this unit will provide an exciting and thought provoking context for learners.

Throughout this unit there are opportunities to develop skills for learning, life and work. The cost and presentation of the design solution to the client are integral to the success of the project, developing learner s enterprise and presentation skills. The majority of tasks within the unit support the development of learner s numeracy and literacy skills. Learners also take part in two group work activities developing their employability skills and capacities as effective contributors. The design challenge develops learner s creativity and thinking skills requiring them to understand and apply knowledge to analyse, evaluate and solve a design problem, developing their capacities as successful learners and effective contributors who are able to think creatively, solve problems and make reasoned evaluations (The Scottish Government, 2008: 22).

As this unit is designed to fulfil outcomes from National 4 and 5 courses, summative assessment will be conducted under SQA guidelines. Formative assessment will also be used throughout the unit to support the learning process, inform next steps and provide a good basis for reporting on progress (The Scottish Government, 2008: 40). Learners will receive feedback on their designs and presentations from the client and are asked to undertake self-assessment by evaluating successful and unsuccessful designs at the end of the unit. The incorporation of self-assessment in this unit links to the roles and responsibilities laid out by The Scottish Government (2011: 49) which state that learners should review their own learning through self-assessment and that teachers should involve learners fully in assessment .

FORESTRY ENGINEERING GROUP

Forest Research

Forestry Commission Scotland
Coimisean na Coilltearachd Alba

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