STEM FUTURES

Using Maths Tasks

STEM Works!

Northern Ireland Curriculum

Clean and Green

In these activities, you are a civil engineer. You will need to use your mathematical skills to help your team solve some problems.

About Your Job

Engineers apply science to solve everyday problems. They need to think carefully about how much money their projects will cost to build and to maintain. In the 21st century, engineering solutions also need to take environmental concerns into account and support sustainable development: they should meet people's needs now and make sure that future generations' needs can be met. So engineers have to be careful how they use natural resources.

Designing sustainable schools is one important area that engineers in Northern Ireland are working on. They have to consider, for example:

- how to reduce waste;
- what they can recycle;
- how much energy the school needs to run; and
- what type of materials to use.

When engineers design a classroom, they also have to make sure that teachers and pupils will be able to hear each other properly. This includes thinking about acoustics: how sounds are transmitted, absorbed and reflected.

To take all these things into account and make the best decisions for the school, society, the economy and the environment, engineers need to use mathematics.

About Your Task

Your team is going to design a new sustainable school for your local area. The local council has asked you to make sure that:

- the school is based on sustainable development;
- you save energy and costs where you can; and
- the classroom design allows clear verbal communication between pupils and teachers.

Part of your job will be to think about how your new school will source its electricity and lighting. Your total budget is:

- £50 000 to buy the items you need to power and light the school; plus
- £15 000 per year (an operational budget) to provide lighting and power to the school.

ACTIVITY 1

The Cost of Electricity

The school will need whichever method you choose for providing electricity to last a long time. You're going to work out the costs of several methods over a design life of 50 years.

1.1 (a) What is your total operational budget for the school over a period of 50 years?

(b) Taking initial costs into account, what is your overall budget for these 50 years?

Your colleagues have estimated that the school will use about 30 000 kilowatt-hours (kWh) of electricity per year. (This doesn't include any energy-saving technologies you might choose to use later). This electricity could come from one of three different sources, as shown in Table 1.

Table 1: Options and Cost of Producing Electricity

Technology	Purchase Cost	Rates and Running Costs
Option 1: Standard electricity provider only	£0.00	30 000 kWh at 13.19p per kWh
Option 2: Standard electricity provider plus solar power (Solar power can generate 15 000 kWh per year)	£50 000.00	13.19p per kWh for 20 000 kWh of electricity Solar power for the remaining 10 000 kWh Sell 5000 kWh of solar power per year back to the grid at 15.00p per kWh Annual maintenance costs: 1% of purchase price
Option 3: Standard electricity provider plus wind power (Wind power can generate 25 000 kWh per year)	£20 000.00	13.19p per kWh for 15 000 kWh of electricity Wind power for the remaining 15 000 kWh Sell 10 000 kWh of wind power per year back to the grid at 15.00p per kWh Annual maintenance costs: 1% of purchase price

1.2 Over the 50 years, which option will be the least expensive for the school?

ACTIVITY 2

Light Options

You might be able to reduce the 30 000 kWh of electricity that the school needs, depending on the type of lighting that you choose. You have three options, as Table 2 shows.

Table 2: Options for School Lighting

Technology	Units Needed and Purchase Cost	Rates and Running Costs
Option 1: Standard light bulbs	500 at £1.00	60 W bulb on 8 hours a day at 13.19p per kWh Annual replacement: 10% of bulbs
Option 2: Energy saving light bulbs	500 at £8.00	13.19p per kWh for 20 000 kWh of electricity Solar power for the remaining 10 000 kWh Sell 5000 kWh of solar power per year back to the grid at 15.00p per kWh Annual maintenance costs: 1% of purchase price
Option 3: Sun pipes/Skylights	300 at £100.00	13.19p per kWh for 15 000 kWh of electricity Wind power for the remaining 15 000 kWh Sell 10 000 kWh of wind power per year back to the grid at 15.00p per kWh Annual maintenance costs: 1% of purchase price

2.1 Over the 50 years, which option will be the least expensive for the school?

How much electricity can the school save by using this option instead of the other two technology options?

2.2 How much money can the school board save by using natural light to power and light the school?

2.3 Based on all the information in your client's budget, can you afford the technologies you would like to choose for electricity and lighting? Do you have to make any compromises? If so, what could you do?

2.4 What advantages and disadvantages are associated with generating electricity from technologies that rely on natural light?

ACTIVITY 3

Classroom Acoustics

You experience acoustics in action all the time. For example, when you make a sound in an empty room, you might notice that there are echoes. This is because bare walls, floors and ceilings absorb very little of the sound, so you hear some sound reflecting off these surfaces as an echo. In a room with furniture, carpet and curtains, however, you might notice very few echoes – or none at all – because the materials absorb a lot of the sound.

By calculating what's called **reverberation time**, you can make sure that the acoustics in your classroom design are suitable. If the reverberation time is **low**, it means:

- most of the sound is being **absorbed**;
- very little sound is reflected or transmitted; and
- it might be difficult for teachers and pupils to hear one another.

If the reverberation time is **high**, it means:

- most of the sound is being **reflected**;
- this adds reflections (or echoes) to the original sound; and
- it might be difficult for teachers and pupils to hear one another clearly.

The reverberation time for your classroom should be from 0.7 to 0.8 seconds.

To calculate reverberation time, engineers and scientists usually use:

- a gun that fires blanks;
- a sound level meter (or 'decibel meter') that measures how long it takes for the noise from a gunshot to be reduced by 60 decibels; and
- a mathematical formula – Sabine's formula.

Before you can use Sabine's formula, you need to find out the room's absorption **(A).** This takes into account:

- the area of each surface **(s)** of the room (walls, ceiling and floor; teachers and pupils also absorb sound, but this is usually ignored in calculations); and
- the absorption coefficient **(α)** of each type of surface, which is usually determined by a laboratory test.

The formula to calculate a room's absorption is:

$$A = \sum s\alpha$$

Sabine's formula is:

$$T = 0.161\frac{V}{A}$$

In the formula:

T is the reverberation time, in seconds

V is the volume of the room, in cubic units

A is the absorption of the room, in square units.

Classroom Data

- A cuboid classroom has a height of 3 metres and walls of 4 metres and 6 metres.
- The ceiling is made of plasterboard that has an absorption coefficient of 0.12.
- Three of the walls are made of blockwork with plasterboard, which has an absorption coefficient of 0.18.
- The other wall, one of the longer ones, is entirely made of glass with an absorption coefficient of 0.05.
- The floor is clad with timber, giving an absorption coefficient of 0.15.

Use the background information provided and the classroom data to solve the following problems.

3.1. Calculate the reverberation time of this classroom, and determine whether it is suitable.

3.2 A similar room was tested using a blank-firing gun and a sound level meter. For educational purposes, the children were present (all wearing hearing protection). The measured reverberation time was lower than expected. Can you think of a possible explanation? What is it?

3.3 What would happen to the reverberation time if all the walls were made of glass? Is this an acceptable reverberation time for a classroom?

Evaluating Your Learning and Success Criteria

At the end of the task, you could work in pairs or as part of a group to review and evaluate your own and each other's work. You can gauge how successful you were in this task by considering how well you were able to demonstrate that you can:

- choose the appropriate materials, equipment and mathematics to use in a particular situation;
- use mathematical knowledge and concepts accurately;
- work systematically and check your work;
- use mathematical understanding and language to ask and answer questions, talk and discuss ideas and explain ways of working;
- round to an appropriate number of decimal places and significant figures;
- manipulate algebraic expressions, equations and formulae;
- make informed decisions involving money; and
- solve complex problems involving perimeter, surface area and volume.

You could also consider the following:

- how your approach to the activities compared with others;
- your strengths and weaknesses;
- what you might do differently if you were to repeat the activities;
- what aspects of your work you can improve upon; and
- setting targets and focus for development.