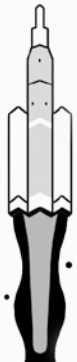

ENGINEERS MAKING A DIFFERENCE

TEACHER'S GUIDE

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WELCOME TO THE ENGINEERS MAKING A DIFFERENCE TEACHER'S GUIDE!

We hope that this resource empowers you to use the book *Engineers Making A Difference,* along with the Timeline of 100+ Feats of Engineering and the engineering topic posters, to provide students with a rich learning experience that's all about the amazing world of engineering.

You can find the video case studies along with any downloadable resources on our website:

www.engineers-making-a-difference.com

Any page references given in this guide refer to pages in the book *Engineers Making A Difference.* This guide suggests a series of activities for teachers to engage students in learning about engineering – a field that influences our lives in a multitude of ways (even if we might not realise it!). The activities have been put together with the English National Curriculum in mind, with links and learning objectives set out clearly at the start of each one. The first 20 activities offer in-depth suggestions for engaging students with the engineer's profiles and topics from the main book; some are hands-on activities and others are discussion-, research- or presentation-based. Flip to the back of the guide for some shorter, quick-fire suggestions to prompt discussions and student thinking.

Teachers will note that many of these tasks serve as a launching point to extend learning beyond the *Engineers Making A Difference* book, the Timeline of 100+ Feats of Engineering and the engineering topic posters. Using *Engineers Making A Difference* as an anchor text, we encourage teachers to conduct background research and explore the context of the various topics before engaging in these tasks to ensure that students are exposed to sources and information that address the various aspects of a particular topic in an inclusive manner. We are so excited to provide you with this resource and we thank you in advance for providing your students with a rich and meaningful STEM- and careers-focused learning experience!

ACTIVITY 1:
DESIGN AND BUILD AN EARTHQUAKE-PROOF BUILDING

NATIONAL CURRICULUM LINKS IN THIS ACTIVITY

Geography

- Understand, through the use of detailed place-based exemplars at a variety of scales, the key processes in physical geography relating to geological timescales and plate tectonics.
- Understand how human and physical processes interact to influence, and change landscapes, environments and the climate; and how human activity relies on effective functioning of natural systems.

Science

- Chemistry: the structure of the Earth.

SUGGESTED RESOURCES

- Professor Anastasios Sextos' profile (pages 68–71)
- Video case study about Professor Anastasios Sextos www.youtube.com/watch?v=HAoGdLZV2nQ
- 'Tectonic hazards – earthquakes and tsunamis' www.bbc.co.uk/bitesize/topics/zn476sg/articles/zc4rcmn
- 'Engineering Challenge: Earthquake Shake Table' www.youtube.com/watch?v=Wzw8fvueUbI

EQUIPMENT

- Two pieces of heavy cardboard or thin wood (worn out ring binders work well)
- Four rubber balls or bouncy balls, each measuring about 2.5 cm
- Two large rubber bands
- A selection of different materials with which to build a structure, such as building blocks, sugar cubes, lollipop sticks, marshmallows, spaghetti, pipe cleaners, paper clips or playing cards

LEARNING OBJECTIVE

Test different hypotheses for earthquake-proof buildings, including the ones mentioned in the chapter.

INTENDED OUTCOME

Construct an earthquake-proof building.

ACTIVITY

In this activity, students will begin by investigating how earthquakes work and the impact they have on the human population.

Start by ascertaining students' levels of prior knowledge in relation to earthquakes. If needed, allow them to use the KS3 BBC Bitesize online resource 'Tectonic hazards – earthquakes and tsunamis' listed above, to support their understanding of how earthquakes work and the management of their impact. Identify what pieces of the resource to use depending on the students' prior knowledge levels.

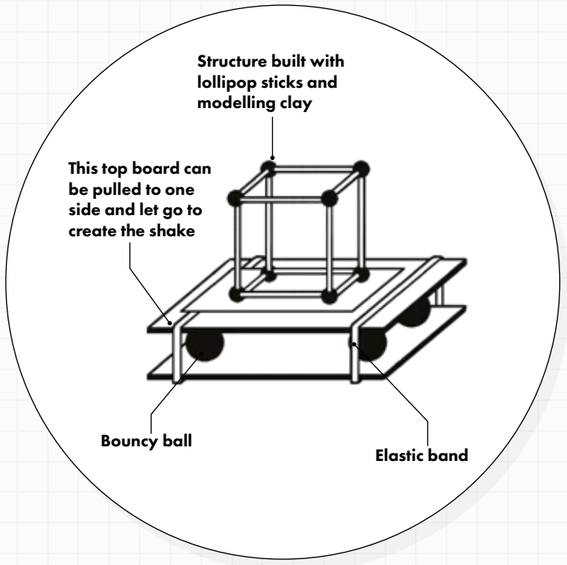
In order to access this activity, students need to know that earthquakes cannot be prevented and understand the impact of seismic activity on humans – including on infrastructure.

Once students understand the impact of earthquakes, introduce them to the work of Professor Anastasios Sextos by asking them to read his profile and view the video case study.

Introduce students to the testing procedure for earthquake-proof structures. You can build your own shake table or get the students to do this. This video resource gives details of the instructions: 'Engineering Challenge: Earthquake Shake Table'.

Instructions

- Place one board on top of the other and put two elastic bands around the short edges, about 2.5 cm from each end.
- Separate the two cardboard layers and place two balls at each end, roughly underneath the elastic bands.
- Once assembled, try pulling and releasing the top board of the table. This should cause a movement that mirrors an earthquake and can vary in severity depending on how far you pull it.



Once the shake table is ready, ask students to build a variety of different structures using the materials provided. Encourage students to be creative and build and test the stability of a variety of structures.

Ask students to think carefully about their choices. They can try structures made from wood or blocks and then try different arrangements such as pyramids. They can use flexible elements, such as marshmallows, to add bend to the structure, or add weight in different places to see what effect this has.

Once the designs have been tested, students can discuss the effectiveness of the options that they built. Ask students what barriers there could be to effective construction of earthquake-proof buildings in different areas of the world or in different environments. Encourage students to think about cost in areas that are less developed or accessible.

Extend the activity by asking students how they might change their structures in the light of the results from the shake table tests and if they felt there were any advantages to some of the simpler structures. For example, do they need to add more flexibility or does the structure need to be more rigid? What happened when the structure was simple versus more complicated? If they used marshmallows, should they add more or remove some?

ACTIVITY 2 :
MODERN METHODS OF CONSTRUCTION: 3D PRINTING

NATIONAL CURRICULUM LINKS IN THIS ACTIVITY

Design and technology

- Build and apply a repertoire of knowledge, understanding and skills in order to design and make high-quality prototypes and products for a wide range of users.
- Develop and communicate design ideas using annotated sketches, detailed plans, 3D and mathematical modelling, oral and digital presentations and computer-based tools.

Science

- Applying a knowledge of a range of techniques, apparatus and materials to select those appropriate both for fieldwork and for experiments.

SUGGESTED RESOURCES

- Building with MMC poster (or pages 76–77)
- '3D-printed homes for sale' www.youtube.com/watch?v=A7-PATZNZYY

EQUIPMENT

- Paper
- Drawing equipment
- Modelling clay

LEARNING OBJECTIVE

Consider how engineers can use modern manufacturing techniques (3D printing) to manufacture buildings and apply these techniques to your own model structure.

INTENDED OUTCOME

Design and '3D print' a model of a house, considering modern construction methods.

ACTIVITY

In this activity, students will experiment with modern methods of construction (MMC) to simulate 3D printing techniques using a range of materials. Introduce students to the different types of MMC by having them read through the poster (or pages 76–77 in the book) – different students could read each box out loud.

Next, discuss how 3D printing is used in construction – 3D printing is an additive manufacturing technique, whereby layers of material are distributed across a 2D surface in a mapped pattern to create a 3D object once fully built.

Assess students' understanding of basic materials and their properties; whether they are aware of key terms, such as solid, rigid, viscous, flexible, liquid etc. Introduce these terms and suggest suitable materials for each category, and a suitable application for each. For example, steel girders are used in a skyscraper's frame because they have a high level of compressive strength and are very durable. They are strong and can carry the weight of different floors as well as lasting for a long time, which is essential for a building.

Once key terms have been explored, ask students to research additive manufacturing so they can understand what it is.

A video that explores 3D printed homes can be shown – for example the video '3D-printed homes for sale' that is listed in the resources. Students should take notes and refer their newly acquired key terminology to the video to provide additional context.

Main task

Ask students the following questions:

- What makes 3D printing a building useful for engineers and homeowners once the building is completed?
- What material properties does 3D printing with concrete give to the building?

Explain that buildings are built using foundations and plans. As engineers, it is important that we follow carefully laid out plans to ensure that our buildings match their specifications. Ask students to design a simple building using the correct scale on an A4 piece of paper. Make sure that each part is annotated and accurately measured.

Next, students should roll out some modelling clay into long, thin tubes and use them to start 'piping' the layers of their building, following the plan that they have drawn. Students should build up their structure layer by layer, replicating what they have just seen in the video. They should repeat this process until they have created a walled structure that matches their original blueprint.

Assessment

Ask students what issues they faced when creating their building and troubleshoot with them in demonstration. Make sure they understand that the layers contribute to additive manufacturing of the 3D printed structure. Ask students to review the outcome of the building and evaluate their manufacturing process. How well did they manage to create the walls of their building? What would they do differently if they were to approach this task again?

Ask students to pretend they are an estate agent trying to sell their house. They should write a short paragraph of information about their building and the benefits of how it was constructed. Students can then read their paragraphs to the rest of the class.

ACTIVITY 3:
FLOOD DEFENCES

NATIONAL CURRICULUM LINKS IN THIS ACTIVITY

Science

- Pay attention to objectivity and concern for accuracy, precision, repeatability and reproducibility.
- Evaluate risks.

Geography

- Physical geography relating to: geological timescales and plate tectonics; rocks, weathering and soils; weather and climate, including the change in climate from the Ice Age to the present; and glaciation, hydrology and coasts.
- Understand how human and physical processes interact to influence and change landscapes, environments and the climate; and how human activity relies on effective functioning of natural systems.

SUGGESTED RESOURCES

- Ayo Sokale's profile (pages 22–25)
- Malithi (Milly) Hennayake's profile (pages 64–65)
- 'Geography | KS3 | Responses to Flooding | BBC Teach' www.youtube.com/watch?v=MBA9vldDCek

EQUIPMENT

- Construction bricks
- Plastic pipes
- Plastic containers
- Water

LEARNING OBJECTIVE

Explore and compare the design features of a range of flood defence systems.

INTENDED OUTCOME

Build and evaluate a flood defence system.

ACTIVITY

Introduce students to a range of flood defences that have been built across the UK. These may include the Tull Way Flood Alleviation Scheme from Ayo's profile, the Thames Barrier and the embankment of the River Severn. Ask students to work individually or in groups and create a list of the key characteristics of flood defences. The video listed in the resources may help with this.

Here are some of the characteristics for guidance:

- Fixed – permanent fixtures installed at the relevant area, e.g. dams, weirs.
- Demountable – fixed into areas but can be modified pre flood to add extra levels of support, e.g. flood walls.
- Temporary – put in place pre flood and removed post flood, e.g. portable metal barriers.

Ask students to consider the impact these flood defences may have on the environment. Introduce the terms 'carbon footprint' and 'biodiversity' if students don't mention them and ensure they understand what they mean. Challenge students to consider the relationship between the human action and design of the flood defence and its impact on the environment. This activity provides an opportunity to consider a career in civil engineering, referring to Ayo Sokale and Milly Hennayake's profiles.

Discuss the different types of flood defences with students – this might include weirs and bunds. They should consider how these models can be adapted to support the specific environment. Using the examples provided in the book, encourage students to consider how both defence structures have an impact on the environment and how the carbon footprint of their construction could be minimised.

Provide students with pipes and construction bricks and challenge them to design and build a model of a flood defence system.

Ask them to research and consider the following:

- Find a local area that is in need of flood defences – how will their defence system meet the needs of that area?
- Protection against flood water – will the flood defence work? Are there any potential hazards caused by the flood defences, for example, surface run off, dangerous re-direction of water, erosive hazards along the riverbank?
- Materials – what materials will they use for their flood defence?
- Expense – are the materials affordable and durable?
- Environmental cost – will the materials and design complement the environment and sustain biodiversity?

As a class, ask students to assess the models on the above criteria and choose the two that they think will be the most successful. Create a flow of water to test these two flood defence models and evaluate which one works best. Discuss with students how the defences might be improved following the results of the tests.

ACTIVITY 4 :
REDUCING PLASTIC POLLUTION

NATIONAL CURRICULUM LINKS IN THIS ACTIVITY

Science

- Understand that scientific methods and theories develop as earlier explanations are modified to take account of new evidence and ideas, together with the importance of publishing results and peer review.

Design and technology

- Understand developments in design and technology, its impact on individuals, society and the environment, and the responsibilities of designers, engineers and technologists.

SUGGESTED RESOURCES

- Dr Natalia Falagán Sama's profile (pages 20–21)
- Climate and Environment chapter (pages 28–45)
- Dr Elena Dieckmann's profile (pages 108–11)
- Video case study about Pierre Paslier www.youtube.com/watch?v=DBNIjzg6wFQ
- 'The world's plastic pollution crisis explained' www.nationalgeographic.com/environment/article/plastic-pollution
- 'Fast facts about plastic pollution' www.nationalgeographic.com/science/article/plastics-facts-infographics-ocean-pollution
- Notpla www.notpla.com

LEARNING OBJECTIVE

Investigate the impact of plastic pollution and how engineers are developing alternatives to plastic to reduce our environmental impact.

INTENDED OUTCOME

A persuasive presentation aiming to reduce the amount of plastic packaging used in school.

ACTIVITY

In this activity students will focus on the impact of plastic pollution and will learn about the fascinating work of Pierre Paslier and his company Notpla. Prior to completing this activity, ask students to keep a log of all the products they use in a day. They should record the product, why they needed to use it and the type of packaging it came in.

Start the activity by asking students to discuss their product logs. Focus on the number of products that use plastic in their packaging. At this point ask students to consider whether or not that plastic was required. In order to do this, students will need to think about why that plastic was used. For example, a thin layer of plastic is often used to cover cucumbers so the food product isn't contaminated by dirt

or germs in the environment or by people touching them. The plastic can also help to prolong the life of food and other items (see Dr Natalia Falagán Sama's profile). Some uses of plastic can be justified, however others, for example in the packaging of toys, could be avoided.

Ascertain levels of students' prior knowledge by asking them to discuss and explain why they believe plastic is a significant environmental issue. It is reasonable for teachers to expect students to have some prior knowledge given how topical this issue currently is. Students might discuss:

- Plastic pollution
- Impact on animals
- Single use plastics
- Micro-plastics in the oceans
- Plastics in the food chain

If the discussion touches on all of these points, teachers should feel confident that students have a secure base knowledge and are ready to investigate alternatives to the use of plastics and why this is an important engineering field. If levels of prior knowledge are less secure, the two National Geographic articles listed in the resources might help.

Move on to introduce students to Pierre Paslier, the co-founder of Notpla, who is reducing plastic pollution through the creation of seaweed packaging. Instruct students to read Pierre's profile in the book and discuss why he decided to become an engineer.

Watch the video case study about Pierre and ask students to explore the Notpla website and find out how they make their seaweed packaging.

Ask students to discuss what they thought of Notpla's seaweed packaging and the environmental impact it could have. Can they think of other applications for Notpla's packaging?

Ask students to research other alternatives to plastic packaging that are currently available or in development, and their potential uses. These might include packaging made from:

- Recycled materials
- Organic materials such as soy or hemp
- Corn and cornstarch
- Mushrooms
- Feathers (see Dr Elena Dieckmann's profile)

Students should create a presentation about one or more of the alternatives to plastic packaging, including their current and potential uses. If students are particularly passionate about this issue, they might want to use their presentation as a starting point for a persuasive presentation or pitch to the school's leadership team, with an aim to reduce the amount of plastic packaging bought by the school.

ACTIVITY 5:
3D PRINTED FOOD

NATIONAL CURRICULUM LINKS IN THIS ACTIVITY

Science

- Pay attention to objectivity and concern for accuracy, precision, repeatability and reproducibility.
- Understand that scientific methods and theories develop as earlier explanations are modified to take account of new evidence and ideas, together with the importance of publishing results and peer review.

Design and technology

- Develop specifications to inform the design of innovative, functional, appealing products that respond to needs in a variety of situations.

SUGGESTED RESOURCES

- Farm-Free poster (or pages 26–27)
- 'The Best Food 3D Printers of 2022' https://all3dp.com/1/best-3d-food-printer/
- '3D Printing Food and Cooking It With Lasers' www.youtube.com/watch?v=5IpqV15frb4

EQUIPMENT

- Paper
- Drawing equpiment

LEARNING OBJECTIVE

To research a broad spectrum of food-specific 3D printers and evaluate the strengths and weaknesses of each. Also to design a nozzle for a 3D printer.

INTENDED OUTCOME

Evaluation of current 3D printers to inform the design of your own nozzle. Use your suggested food 3D printer to plan a menu.

ACTIVITY

A food 3D printer works by building up the ingredients, layer by layer, on a build plate – in a similar way to regular 3D printers. This process has many benefits, but currently also has many limits. Material extrusion (squeezing) is by far the most common process for 3D printing food, but needs paste-like materials such as purées, mousses and other viscous foods.

Ask students to research food 3D printers. The suggested resources might be a good place to start. Then, discuss the benefits and disadvantages of 3D printed foods with students. Benefits might include:

- Freedom of designs, e.g. colour, shapes.
- Reduces the amount of waste.
- Can save time.
- Provides different textures to food.
- Might allow for personalised nutrition plans – particularly useful for those with medical needs.

Disadvantages might be:

- Food 3D printers often can't cook the ingredients.
- Currently the technology can't be used to print everything.
- The size of the food that they can print is limited.
- Not everyone has access to the technology.
- If food gets stuck in cracks or spaces in the printer, bacteria can grow – this can pose a health and safety risk.

At the moment, food 3D printers are mostly used for gourmet dining because the technology is still not scalable – it requires more time and development to mature. However, bakers have made headlines for printing edible wedding cake decorations, and for pizza lovers, 3D printed pizzas have been in the works for some time. Plant-based meat is also being 3D printed as a way to mimic the texture of the real thing.

Ask students to think of all the possible combinations that could be made with doughs, mashes, cheeses, jams or even raw meats. What would they print and how would their 3D printer differ from what is currently available? Ask students to create a nozzle for a food 3D printer that can create certain patterns. Students should draw and annotate their nozzle.

Next, ask students to plan a three course menu that their 3D food printer and nozzle could make. Students can present their nozzles and menus back to the rest of the class. Ask them to explain why they have chosen their particular dishes and why they lend themselves to being 3D printed.

ACTIVITY 6:
HYDRO POWERED FUTURE

NATIONAL CURRICULUM LINKS IN THIS ACTIVITY

Science

- Develop understanding of the nature, processes and methods of science through different types of science enquiries that help students to answer scientific questions about the world around them.
- Ensure students are equipped with the scientific knowledge required to understand the uses and implications of science, today and for the future.
- Fuels and energy resources.

Design and technology

- Build and apply a repertoire of knowledge, understanding and skills in order to design and make high-quality prototypes and products for a wide range of users.
- Investigate new and emerging technologies.
- Understand developments in design and technology, its impact on individuals, society and the environment, and the responsibilities of designers, engineers and technologists.

SUGGESTED RESOURCES

- Powering Our Future chapter (pages 46–61)
- 'Hydroelectricity' https://bbc.in/3FmUxx3
- 'WEG helps to generate hydro-electricity for Windsor Castle' www.youtube.com/watch?v=wG-TBJC1R4c
- 'Types of Hydropower Turbines' www.energy.gov/eere/water/types-hydropower-turbines
- 'AMAZING HYDROPOWER TECHNOLOGIES AND HYDROELECTRIC POWER PLANTS' www.youtube.com/watch?v=E2fib7ipvBo
- 'Hydro Power at Home | Hydroelectric Generator DIY' www.youtube.com/watch?v=V3NtSp6aAbs
- Hydro Powered Future worksheet from www.engineers-making-a-difference.com

EQUIPMENT

- A piece of hard recycled plastic that can be cut with scissors into a circle or is already circular. The piece of plastic should be approximately 6 cm in diameter.
- Eight plastic spoons
- A plastic bottle cap or similar
- Glue gun
- Motor
- LED bulb
- Connection wire with a crocodile clip or similar
- Metal skewer

LEARNING OBJECTIVE

Appreciate an alternative, renewable energy source.

INTENDED OUTCOME

A fully operational hydro-generating unit, strong enough to power a small LED.

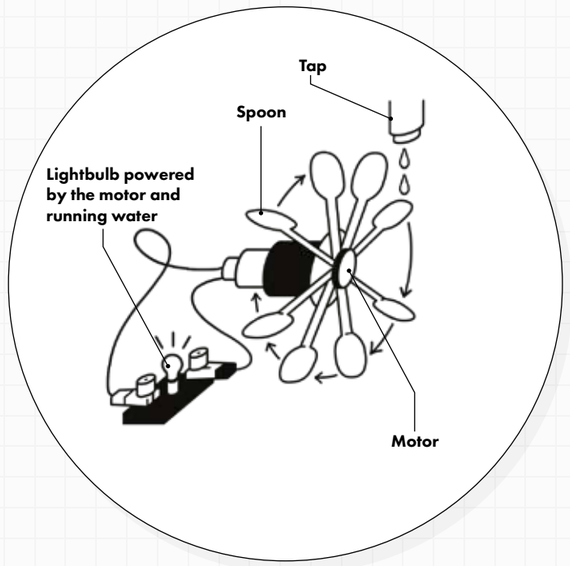
ACTIVITY

Ask students to read chapter 3 of the book and then ask them what other kinds of renewable energy they might know of. Next, introduce them to hydropower – what it is and how it works (see 'Hydroelectricity' BBC Bitesize page listed in resources). Ask students to research where hydropower can be used and find some specific case studies – such as Windsor Castle. The links listed in the resources might provide a starting point for research.

Briefly discuss what the students learnt from this research and have them share some different and interesting hydro-generating units that they found. Once students have a sound understanding of hydropower, you can move on to the main task of making a circuit powered by hydropower.

Teachers can print out an instruction sheet from the Engineers Making A Difference website but it is also recommended that they demonstrate each step to support student understanding. The video 'Hydro Power at Home | Hydroelectric Generator DIY' is also a useful resource.

Split the class into pairs or groups.



Instructions

1. Cut the piece of plastic into a circle with diameter of 6 cm.
2. Score the circle into 8 segments and poke a hole through the middle.
3. Use the glue gun to glue the edges of the plastic spoons to the circle along the score lines, leaving a space around the hole in the middle. Each spoon should be facing upwards. Ensure each spoon is stuck securely and reinforce with glue where needed.
4. Use scissors to cut the screw thread away from the bottle cap so that you are left with only the top circle. Glue it to the exposed edges of the spoons. This should strengthen the structure. You have now created the turbine.
5. Put the rotating part of the motor into the hole that you made in the plastic circle and secure with glue. The aim is that when you turn the turbine it will spin the motor.
6. Use the connection wires to attach each leg of the LED to the pins on the back of the motor.

Test

Run a tap and place the spoons beneath the running water. This should cause the turbine and motor to spin, which generates electricity and lights up the LED.

ACTIVITY 7:
SUSTAINABLE PLANNING

NATIONAL CURRICULUM LINKS IN THIS ACTIVITY

Geography

- Develop contextual knowledge of the location of globally significant places – both terrestrial and marine – including their defining physical and human characteristics and how these provide a geographical context for understanding the actions of processes.
- Human geography relating to: population and urbanisation; international development; economic activity in the primary, secondary, tertiary and quaternary sectors; and the use of natural resources.

SUGGESTED RESOURCES

- Climate and Environment, Powering Our Future and Infrastructure and Construction chapters (pages 28–77)
- Video case studies about:
  - Pierre Paslier www.youtube.com/watch?v=DBNIjzg6wFQ
  - Georgia Lilley www.youtube.com/watch?v=6AhcPzu-xVk
  - Manjot Chana www.youtube.com/watch?v=JIE-H0XVbxI
  - Katriya Sabin www.youtube.com/watch?v=XdkhLpqR4So
- 'The Arcadis Sustainable Cities Index 2022' www.arcadis.com/en/knowledge-hub/perspectives/global/sustainable-cities-index

LEARNING OBJECTIVE

- Suggest how to increase the sustainability of the area that they live in using techniques found in Powering Our Future.
- Design the infrastructure for a sustainable city.

INTENDED OUTCOME

The planning of a new city that would be the most sustainable city in the world.

ACTIVITY

Discuss sustainability as a concept with students. Before completing the activity, students need to know:

1. What does it mean to be sustainable – being able to provide for the current world population without using up all the resources or having a negative impact on the planet.
2. The benefits of sustainability for our planet – these include: reducing energy costs, protecting the environment through the reduction of carbon emissions, reducing pollution, increasing health and wellbeing.

Direct students to the Arcadis website to explore the most sustainable cities around the world. They will need to identify the strengths and opportunities of a variety of cities globally. You could ask them to research three different cities or you could name the cities you want them to use for the case study.

Ask students to use the strengths and opportunities they have identified and suggest ways to improve the sustainability of the area that they live in. Ask them to read the relevant profiles in the book (found in chapters 2–4) and watch the relevant video case studies. Students can then begin thinking about the ways in which a city or town can be made more sustainable.

Using the information gathered from the Arcadis website and the book, ask students to design parts of the infrastructure for a new sustainable city. The students can work in groups.

The new city must use:

1. A low-carbon power supply
2. A sustainable and useful waste-recycling infrastructure
3. A sustainable means of travel
4. Another sustainable element of the students' choice

Ask students to consider whether the sustainable features in their city promote a positive outcome that outweighs the cost to implement these features.

Ask students to prepare a short presentation about their cities and then vote for the one that they think is the most sustainable.

ACTIVITY 8 :
MODEL DNA STRAND

NATIONAL CURRICULUM LINKS IN THIS ACTIVITY

Science

- A simple model of chromosomes, genes and DNA in heredity, including the part played by Watson, Crick, Wilkins and Franklin in the development of the DNA model.

SUGGESTED RESOURCES

- Engineering Genes poster (or pages 94–95)
- 'DNA' www.bbc.co.uk/bitesize/topics/zpffr82/articles/zc8txbk
- 'DNA' https://kids.britannica.com/kids/article/DNA/390730

EQUIPMENT

Per student:

- A selection of coloured beads or modelling clay, in green, red, blue and yellow
- Two pieces of string, elastic or two pipe cleaners (ideally each 30 cm long)

LEARNING OBJECTIVE

To identify components that make up DNA sequences and to demonstrate understanding of bases and bonds.

INTENDED OUTCOME

Constructed model DNA strand.

ACTIVITY

Use the introduction of the Engineering Genes poster (or pages 94–95 in the book), the BBC Bitesize page about DNA and the Britannica Kids page about DNA (listed in the resources) to check students' prior knowledge of DNA.

Ask students the following questions:

- What does DNA stand for? [Answer: Deoxyribonucleic acid]
- Who are the four key scientists who discovered DNA? [Answer: Rosalind Franklin, Maurice Wilkins, James Watson and Francis Crick]
- What base pairs of DNA always pair together? [Answer: A–T and C–G]
- What are genes? [Answer: Small sections of DNA that give the body the code for an inherited characteristic.]

Genes are made up of strings of DNA and each gene codes for a specific protein that does a particular job in the body. Genes are very long but here are some small samples from a few genes that code for proteins in your body:

- myosin (a muscle protein): GTGTGCAGAGGGTTCCTCATGCGTG
- insulin (which helps break down sugar): CTCGAGGGGC CTAGACATTG
- hemoglobin (which carries oxygen in your blood): GTGCACCTGACTCCTGAG
- lactase (which breaks down the sugars in the milk you drink): CTGCACTCCCACCTGGGCAAC

Direct students to make a model of one of the gene samples above. To create their model, students need to add the correct colour beads to the strings in the correct order. They will need different colours for the four bases:

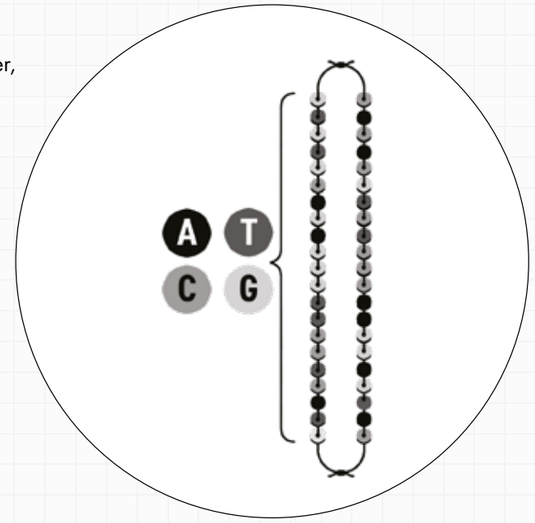
A = Green
T = Red
C = Blue
G = Yellow

Instructions

- Students should begin by tying the two pieces of string together at one end.
- On one of the strings they should thread on the correct sequence of coloured beads to match the gene sample that they have chosen.
- Once they have threaded all of the required beads onto one string they will need to thread beads to complete each base pair onto the second string. For example, if the first bead on string one is red (T), the first bead on string two should be green (A). You might need to remind students of base pairs (A–T and C–G) or write them up on the board.
- Students should keep threading beads according to their sequence until they have finished every pair. Then they should tie both pieces of string to stop the beads falling off.
- Ask students to consider what would happen if they altered part of the sequence.

Extra discussion

Using the information from the Engineering Genes poster, students need to explain the benefits of editing DNA. Students then need to explain why some people might disagree with the concept of genetic engineering. Ask students to come up with their own opinion about genetic engineering – can they list one benefit and one downside? Overall what do they each think? Encourage students to debate and come to a conclusion while acknowledging that there are counter arguments to their point of view.



ACTIVITY 9 :
BUILDING A PROTOTYPE PROSTHETIC HAND

NATIONAL CURRICULUM LINKS IN THIS ACTIVITY

Design and technology

- Develop and communicate design ideas using annotated sketches, detailed plans, 3D and mathematical modelling, oral and digital presentations and computer-based tools.
- Test, evaluate and refine their ideas and products against a specification, taking into account the views of intended users and other interested groups.
- Understand developments in design and technology, its impact on individuals, society and the environment, and the responsibilities of designers, engineers and technologists.

SUGGESTED RESOURCES

- Alan James Proud's profile (pages 80–81)
- Jennifer Olsen's profile (pages 188–189)
- Prototype prosthetic hand worksheet from www.engineers-making-a-difference.com

EQUIPMENT

- Rigid cardboard
- Paper straws
- String
- Tape
- Scissors
- Paper

LEARNING OBJECTIVE

Construct, test and evaluate a product.

INTENDED OUTCOME

A first prototype robotic hand with testing notes and intended refinements.

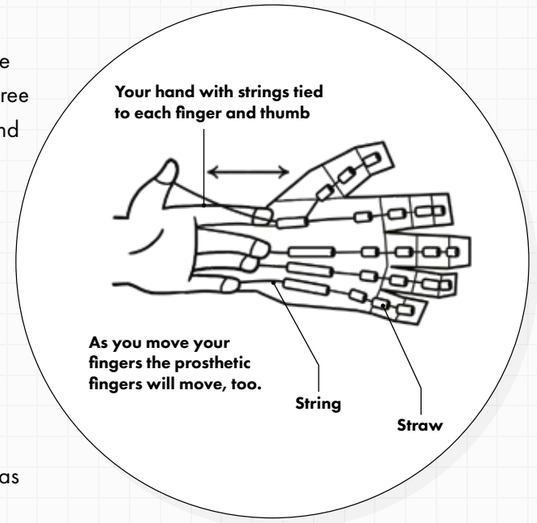
ACTIVITY

Ask students to read Alan James Proud's profile on pages 80–81 of the book and also Jennifer Olsen's profile on pages 188–189. Discuss as a class what Alan and Jennifer do in their jobs, their routes into engineering and also how their jobs help make a difference to people's lives.

Explain to students that in this activity they'll be creating a prototype robotic hand, following a series of instructions.

Instructions

1. Create the prototype hand by cutting a piece of cardboard into the shape of a hand and arm. The palm should be a square roughly 10 × 10 cm, three fingers should be rectangles roughly 2 × 8 cm and the thumb and little finger roughly 2 × 6 cm.
2. Score (but don't cut) the three larger fingers into three equal pieces and the thumb and little finger in two. This will create the joints and allow them to bend.
3. Also score each finger and the thumb where they meet the palm.
4. Cut 22 small pieces of straw each 1–2 cm long.
5. Stick one piece of straw to each section of the fingers and thumb and then the rest on the palm as shown in the diagram.
6. Cut five lengths of string, each about 30 cm long.
7. Tape the end of one length of string to the end of each finger and the thumb.
8. Thread the strings through the straws on each finger and the thumb, and also through the straws on the palm as shown in the digram.
9. Tie each piece of string to the fingers and thumb of your hand (you might have to ask a friend to help you with this).
10. The fingers of the prototype hand can now be moved by pulling each length of string.



Once students have completed their prototype, they will need to thoroughly test its capabilities. Provide a series of differently shaped and weighted objects for students to try and pick up with their prototypes. Ask them to record which objects they are able to pick up, which they have limited success with and which they cannot pick up at all. They should record their results in a table so that they are able to refer back to them as they complete an evaluation of their prototype. This could be in the form of a formal written evaluation or through discussion about what worked well and what didn't.

Once an evaluation has been conducted and students have an idea about what did and didn't work, they should think about how they would redesign their prototype in order to make it more effective or fit for purpose. Students should sketch out their design and annotate it with design ideas, highlighting their improvements and the justification for those changes.

ACTIVITY 10 :
NATURAL COLOUR EXPLOITATION

NATIONAL CURRICULUM LINKS IN THIS ACTIVITY

Science

- Pay attention to objectivity and concern for accuracy, precision, repeatability and reproducibility.
- Evaluate risks.
- Ask questions and develop a line of enquiry based on observations of the real world, alongside prior knowledge and experience.
- Make predictions using scientific knowledge and understanding.

SUGGESTED RESOURCES

- Professor Tom Ellis' profile (pages 106–107)

EQUIPMENT

- Camping stove or food room with a cooker
- Saucepan (preferably old or cheap as it can stain)
- Spoon, non-metallic
- Water
- Red cabbage
- Beetroot
- Lemon
- Turmeric
- Baking powder
- Range of materials such as natural timber, fabrics, paper, cardboard etc.

LEARNING OBJECTIVE

Create and investigate the effectiveness of natural dyes.

INTENDED OUTCOME

Students create and test natural dyes.

ACTIVITY

Start this activity by introducing students to the work of Professor Tom Ellis. Tom works in the field of bioengineering and uses his techniques in the world of fashion. In essence, he creates new materials such as vegan leather and is able to manipulate natural DNA to 'grow colour'.

While it isn't possible to get students to manipulate DNA, it is possible to use the natural colourings of materials to form non-toxic dyes, much like the ones Tom is creating. Further discuss Tom's work and ask students why they think this work is important or required. What are the benefits? Discuss the concerns often associated with toxic dyes, how they are used and the products they might be found in.

Explain to students that in this activity they will create non-toxic natural dyes by using a range of fresh produce.

Provide students with a list of the produce they are about to use and ask them to name the colour they think each item will create.

- **Purple/Blue** – red cabbage
- **Red** – beetroot
- **Yellow** – turmeric

Then, encourage students to think about what colours will be created from the addition of other ingredients.

- **Blue** – purple dye plus ½ tsp of baking powder
- **Pink** – purple dye plus the juice of ½ lemon
- **Green** – blue dye plus yellow dye
- **Orange** – red dye plus yellow dye

Move on to create natural dye. This element requires boiling water and simmering for a while. Teachers might wish to pre-make the dye before undertaking this activity, but note that this experiment works better if the dye is still warm. If resources and safety precautions are suitable, creating the dye might take place in school.

Follow these steps to create as many or few dyes as required:

1. Chop the red cabbage and beetroot.
2. Add the produce to a saucepan (one per saucepan) and add twice as much water as the produce volume.
3. Bring the water to the boil and simmer, stirring occasionally, for five minutes or until there is a rich colour from the produce.
4. Strain the produce from the pot.
5. Place the material to be dyed into the warm dye for a few minutes and then set aside to dry.

Encourage students to experiment with the effectiveness of the dye. They might do this by changing the amount of time they leave the material in the dye. They might also consider the heat of the dye. Ask them to test any factors they think might impact effectiveness.

Ask students to write up an evaluation of their dye experiment. Which dyes worked well? Which did not? How did different conditions affect how well the dye worked? Students should create a table outlining their different tests and their results.

Extra discussion

Move on to discuss the application of natural dyes in the real world. How might these dyes be used to replace more harmful dyes?

ACTIVITY 11 :
INTERNET OF SKILLS WEBPAGE

NATIONAL CURRICULUM LINKS IN THIS ACTIVITY

Computing

- Can evaluate and apply information technology, including new or unfamiliar technologies, analytically to solve problems.
- Are responsible, competent, confident and creative users of information and communication technology.

English

- Write accurately, fluently, effectively and at length for pleasure and information through: writing for a wide range of purposes and audiences.
- Summarising and organising material, and supporting ideas and arguments with any necessary factual detail.

SUGGESTED RESOURCES

- Professor Mischa Dohler's profile (pages 126–129)
- 'The Internet of Skills and 5G: the Democratisation of Technology? With Professor Mischa Dohler' https://teensinai.podbean.com/e/the-internet-of-skills-and-5g-the-democratisation-of-technology-with-professor-mischa-dohler/

LEARNING OBJECTIVE

To explain how the Internet of Skills can be applied to real life uses.

INTENDED OUTCOME

An informative webpage for your school website.

ACTIVITY

Ask students to read the profile of Professor Mischa Dohler and then listen to his section on the podcast listed in the resources list about him 'bringing creativity to engineering and innovation to art'.

Ask students to use the internet to research and explore what the Internet of Skills is and how it could be used.

Once students have completed their research, ask them to design a website about the Internet of Skills. This could be created using Microsoft Word or Powerpoint. The audience for the website should be secondary school students and prospective families reading your school website. The purpose is to inform young people and their families of modern advancements in AI and technology.

The students' webpages should include the following:

1. An introduction and brief history of the internet.
2. What is cloud storage and how do we use it?
3. A definition of what 5G is and explanation of why the speed is significant.
4. A definition of what artificial intelligence is and where it is currently used in modern day society.
5. An outline of Professor Mischa Dohler's concept, the Internet of Skills, and explanation of how it can help people access new skills.
6. A prediction of how the Internet of Skills can be used effectively in the following industries:
   - Healthcare
   - Education
   - Construction
   - Environmental sustainability
   - The arts – with a focus on music
7. An explanation of how important the success of Professor Dohler's concept could be for the human race globally.

Once students have completed their webpages, they can share them with the rest of the class.

ACTIVITY 12 :
STAYING CONNECTED

NATIONAL CURRICULUM LINKS IN THIS ACTIVITY

Computing

- Can evaluate and apply information technology, including new or unfamiliar technologies, analytically to solve problems.
- Are responsible, competent, confident and creative users of information and communication technology.

English

- Write accurately, fluently, effectively and at length for pleasure and information through: writing for a wide range of purposes and audiences, including a range of other narrative and non-narrative texts, including arguments, and personal and formal letters.
- Summarising and organising material, and supporting ideas and arguments with any necessary factual detail.

Geography

- Human geography relating to: population and urbanisation; international development; economic activity in the primary, secondary, tertiary and quaternary sectors; and the use of natural resources.

SUGGESTED RESOURCES

- Staying Connected poster (or pages 130–131)
- Jahangir Shah's profile (pages 120–123)
- Video case study about Jahangir Shah www.youtube.com/watch?v=Ib8dgiYQb1Q
- 'Connecting for Inclusion: Broadband Access for All' www.worldbank.org/en/topic/digitaldevelopment/brief/connecting-for-inclusion-broadband-access-for-all
- UNESCO www.unesco.org/en
- Formal letter writing template worksheet from www.engineers-making-a-difference.com

LEARNING OBJECTIVE

To identify global issues of connectivity and suggest strategies to solve this issue.

INTENDED OUTCOME

Students write a persuasive letter to UNESCO.

ACTIVITY

Task One

Ask students to create a communication technology log identifying their personal use over the course of a week, e.g. streaming Netflix, emailing teachers, keeping in touch on social media, listening to music on Spotify, researching online, etc. Beneath their table, students should write a paragraph explaining how their use over the course of a week has positively impacted their lives, e.g. helping with schoolwork, relaxation, supporting mental health by enabling them to connect with their family and friends.

Task Two

Ask a student to read aloud the following quote from the Staying Connected poster (or pages 130–131): 'Despite progress in communication technology, it's estimated that nearly three billion people (more than a third of the world's population) have never been online.'

This is a staggering statistic considering the advancements in modern technology. The World Bank is working on a strategy to understand and reduce poverty by increasing the number of people who have access to the internet. Ask students to write a persuasive letter to UNESCO (The United Nations Educational, Scientific and Cultural Organization) encouraging them to partner with the World Bank to reduce the number of people who have never been online.

Their letter must link to the content from the chapter, including Jahangir Shah's profile. Show students Jahangir's video case study, which shows the complexities of providing television services. An additional key area for students to focus on is how the increase of connectivity will benefit people in the sectors of:

- Education
- Healthcare
- Mental health and wellbeing
- Employment
- Personal development

Next, ask students to read out the sections on Li-Fi and SpinLaunch from the poster and check their understanding of these concepts.

Ask students to write a short paragraph to persuade:

- NASA to continue their partnership with SpinLaunch to support the advancements in low Earth orbit (LEO) satellite technology.

or

- Hospitals to consider using Li-Fi technology.

Challenge students to explain how the success of Li-Fi technology can boost the effectiveness of the 'Internet of Skills' concept, with a specific focus on its uses in hospitals and medical operations.

ACTIVITY 13 :
DESIGN AND BUILD AN ASSEMBLY LINE

NATIONAL CURRICULUM LINKS IN THIS ACTIVITY

Design and technology

- Develop and communicate design ideas using annotated sketches, detailed plans, 3D and mathematical modelling, oral and digital presentations and computer-based tools.
- Test, evaluate and refine their ideas and products against a specification, taking into account the views of intended users and other interested groups.

SUGGESTED RESOURCES

- Bethany Cousins' profile (pages 134–137) and Kate Todd-Davis' profile (pages 142–145)
- Factories of the Future poster (or pages 148–149)
- 'How to Make a Conveyor Belt (very easy)' www.youtube.com/watch?v=UsF5Isjdgw4
- 'How to Make a Conveyor Belt very easy' www.youtube.com/watch?v=WTtT92Gr1CY

EQUIPMENT

- Cotton reels or PVC pipe
- Cardboard
- Fabric
- Lollipop sticks
- Glue
- Dowels
- A test piece such as a small rubber or paper clip
- Motor
- Battery
- Wires

LEARNING OBJECTIVE

Consider how engineers and manufacturing technologists use assembly lines to help manufacture a product. Investigate how they work, taking into consideration the initial principles of conveyor belt systems.

INTENDED OUTCOME

Students will research and investigate how assembly lines have developed, from their early beginnings through to modern day factory settings.

Through trial and error, students will build a simple model of a conveyor belt, using cotton reels, fabric and dowels. Students will test their conveyor belt and take a small test item along it.

ACTIVITY

Ask students if they have seen a conveyor belt in real life (most will have in the supermarket or airport) and if they know how it works. Then ask them to research conveyor belts – how they work, where they are used and why they are useful.

Next, ask students to draw a plan for a model conveyor belt that is made using the equipment provided.

They will need to consider the following aspects:

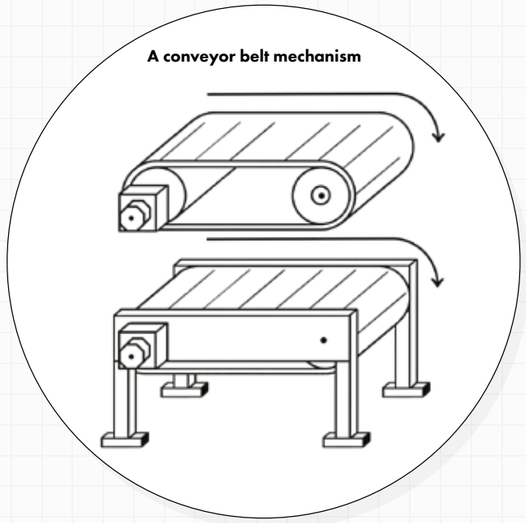
1. How a conveyor belt works.
2. What materials are needed to make it.
3. How conveyor belts are structurally supported.
4. How big is the item that it needs to move.

Once students have planned their designs and considered the materials that are available to them, they should build their conveyor belt. Students should be encouraged to use trial and error to find the best construction method. If they struggle with this they can use the YouTube videos suggested in the resources.

Students should consider how to make a frame that supports their conveyor belt. The frame should not inhibit the belt mechanism from turning and the belt should be able to support the test piece as it travels along the system.

Once the students have made their models, they should use them to transport the test piece from start to finish. Students should then evaluate their structures and suggest any amendments.

As a follow on task, students could be encouraged to construct a number of model conveyor belts and get them to function simultaneously. This mimics how an item might move through a factory. Students should experiment with conveyor belts that move at different speeds, heights and angles.



ACTIVITY 14 :
BATTERY POWERED CAR

NATIONAL CURRICULUM LINKS IN THIS ACTIVITY

Science

- Use appropriate techniques, apparatus and materials during fieldwork and laboratory work, paying attention to health and safety.
- Forces: resistance to motion of air.
- Forces being needed to cause objects to stop or start moving, or to change their speed or direction of motion.

Design and technology

- Build and apply a repertoire of knowledge, understanding and skills in order to design and make high-quality prototypes and products for a wide range of users.
- Develop specifications to inform the design of innovative, functional, appealing products that respond to needs in a variety of situations.
- Test, evaluate and refine their ideas and products against a specification, taking into account the views of intended users and other interested groups.
- Understand how more advanced electrical and electronic systems can be powered and used in their products.

SUGGESTED RESOURCES

- Battery-Powered Transport poster (or pages 162–163)
- 'How to make Amazing F1 Racing Car - Out of Cardboard DIY' www.youtube.com/watch?v=1HHFpzFOfko
- 'How To Make a Battery Powered Car | Coolest Toy Car From Scratch' www.youtube.com/watch?v=9kjm_xMfbr8

EQUIPMENT

- Wooden skewers
- Four bottle tops of equal size
- Elastic band
- Battery
- Cardboard
- Glue gun
- Motor
- Connection wires with a crocodile clip or similar
- Paper straws
- Scissors

LEARNING OBJECTIVE

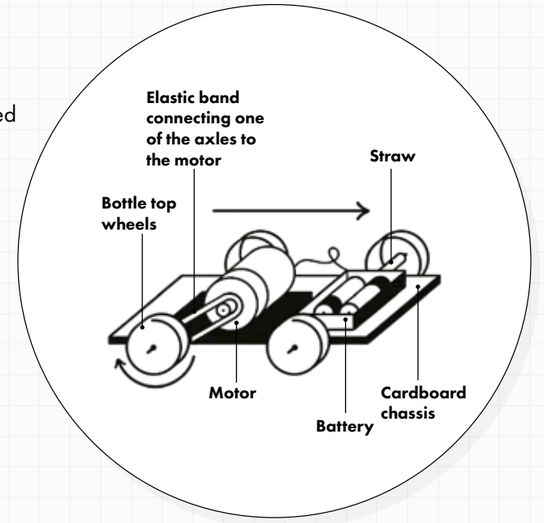
To apply knowledge of electrical circuits in order to build a battery-powered vehicle.

INTENDED OUTCOME

A fully operational battery-powered vehicle.

ACTIVITY

In this activity, students will create their own battery-powered vehicle. Start by having students read the section 'How a battery works' on the Battery-Powered Transport poster (or pages 162–163). Ensure they understand this. Next, ask them to build and test a small battery-powered car.



Instructions

1. Cut a rectangle out of cardboard and glue two straws onto it – one at the front and one at the back. This is the chassis (base frame) of the car.
2. Using the scissors, carefully poke a hole in the centre of each of the four bottle tops.
3. Poke one wooden skewer through one of the bottle tops and hot glue in place. Then thread the skewer through one of the straws. Poke the other end of the skewer through another bottle top and glue in place.
4. Poke the other wooden skewer through another bottle top and hot glue in place. Then thread the skewer through the other straw.
5. Put an elastic band on the skewer and then poke the skewer through the final bottle top and glue in place. You have now made your wheels and axles.
6. Flip the chassis over. Make a simple circuit that includes a motor, a battery and a switch and glue it all to the top of the chassis. You will need to attach your elastic band to the rotating part of the motor, so ensure that you glue it close enough.
7. Put the elastic band around the motor so that when it turns it causes the back wheels and axle to turn. Ensure that the elastic band can turn freely.
8. Now, when you turn the switch to 'on' your car should move! Make any adjustments required to ensure that it runs smoothly.
9. Lastly, decorate your car and make an aerodynamic covering for it out of cardboard or any other materials that you like.
10. Test your vehicle and get ready to race!

Students can race their vehicles to test which one performs the most successfully. Key evaluations for students to consider are:

- How did their vehicle perform?
- What modifications could be made to improve the performance of their vehicle?
- How effective were the materials used?
- How would they scale up the size of their vehicle without impacting performance?

Extra discussion

Choose one of the developments in battery technology from the poster – 'The Powerwall', 'Solid-state batteries' or 'Graphene' – and explain the impact it will have on the use of battery-powered transport for future generations.

ACTIVITY 15:
AERODYNAMICS IN AEROSPACE ENGINEERING

NATIONAL CURRICULUM LINKS IN THIS ACTIVITY

Science

- Making and recording observations and measurements using a range of apparatus and methods.
- Evaluating methods and suggesting possible improvements and further investigations.
- Present observations and data using appropriate methods, including tables and graphs.
- Interpret observations and data, including identifying patterns and using observations, measurements and data to draw conclusions.

Design and technology

- Identify and solve their own design problems and understand how to reformulate problems given to them.
- Test, evaluate and refine their ideas and products against a specification, taking into account the views of intended users and other interested groups.

SUGGESTED RESOURCES

- Krystina Pearson-Rampeearee's profile (pages 156–157)
- Video case study about Krystina Pearson-Rampeearee www.youtube.com/watch?v=V9DgBb4a3-o
- Paper plane worksheets from www.engineers-making-a-difference.com
- 'How to Fold Five Incredible Paper Airplanes' www.youtube.com/watch?v=JhYZy1ugI3Q

EQUIPMENT

- A4 paper
- Tape measure
- Small items to use as weights, e.g. paperclips

LEARNING OBJECTIVE

Understanding simple aerodynamics and the value of testing, evaluation and iteration in design.

INTENDED OUTCOME

Create paper aeroplanes and make amendments to improve the aerodynamic performance of these planes.

ACTIVITY

Introduce students to the idea of aerospace engineering by reading Krystina Pearson-Rampeearee's profile and watching her video case study. Ask students what they think are the key things to consider when building an aeroplane. Then, introduce students to the idea of designing their own paper aeroplane.

Students can use the paper plane worksheets from www.engineers-making-a-difference.com and also the suggested YouTube resource to learn how to fold their own paper aeroplanes. Once students have created their first design, they need to test the flight performance of their paper aeroplane.

Ask students to draw a chart to track the flight data of their paper aeroplane. They should include the following columns:

- Test number
- Distance
- Observation
- Amendment

Ask students to fly their planes and observe how they fly. Do they fly straight? Do they curve up or down? Do they spin? Students should write these observations and how far their plane flies in the chart. Based on the observations from the first test flight, ask students to amend the designs of their aeroplanes, e.g. refold, flatten, bend a wing, add a weight such as a paperclip, change throwing technique etc. Repeat the process as many times as needed and continue to improve the design to maximise the distance flown.

Once students are happy with their designs ask them to create another paper aeroplane using a different method. Follow the same 'observe, measure, amend and repeat' process.

Students can follow the process for as many different designs as they like.

Ask students to consider the following:

- Did your amendments always increase the flight distance of the paper aeroplane?
- Why is it important to repeat the process multiple times using the same initial design?
- Out of your different designs, which was the most effective and why?
- Create an alternative column to measure the effectiveness of your plane other than distance, e.g. time spent in the air before landing.

Ask students to choose the aeroplane of theirs that they think flies best and compete with their classmates to find the plane that flies the furthest.

Have students consider Krystina's profile again. She manages systems that fly and her primary focus is on assembling the full system. Therefore, Krystina is involved throughout the full engineering lifecycle of a plane, including in testing. Why is it important for aerospace engineers like Krystina to test and amend flying machines before they are put into use?

ACTIVITY 16:

DESIGN AND BUILD AN INFORMATIVE INTERACTIVE EXPERIENCE

NATIONAL CURRICULUM LINKS IN THIS ACTIVITY

Design and technology

- Use research and exploration, such as the study of different cultures, to identify and understand user needs.
- Identify and solve their own design problems and understand how to reformulate problems given to them.
- Develop specifications to inform the design of innovative, functional, appealing products that respond to needs in a variety of situations.

Geography

- Human geography relating to: the use of natural resources.
- Understand how human and physical processes interact to influence and change landscapes environments and the climate; and how human activity relies on effective functioning of natural systems.

SUGGESTED RESOURCES

- Michelle Hicks' profile (pages 174–177)
- 'Chessington World of Adventure: Tiger Rock' www.chessington.com/explore/theme-park-zoo/rides-attractions/tiger-rock/
- 'Chessington Theme Park and Zoo map' www.chessington.com/explore/theme-park-zoo/park-map/
- 'What is the problem with plastic?' www.bbc.co.uk/bitesize/articles/z4d62v4
- 'Tiger Rock - 4k On ride POV (Chessington World of Adventures)' www.youtube.com/watch?v=x4HMWeE6d9I

LEARNING OBJECTIVE

Educate people about plastic pollution in an innovative way using engineering.

INTENDED OUTCOME

A plan of a theme park area or ride that shows the negative impact of plastic pollution on the planet.

ACTIVITY

In this activity students will use their knowledge about plastic pollution to create a resource with the intention of educating others. If necessary, use the BBC Bitesize internet resource listed above to ensure that students understand how plastic pollution impacts the planet and life on it. Explain to students that the outcome of the activity is to design a theme park ride or area that shows the negative impact of plastic pollution.

Read Michelle Hicks' profile (pages 174–177) with students and discuss her work. In her profile, Michelle explains how she created the Land of the Tiger at Chessington World of Adventures Resort. Explain that the aim of this ride was to entertain people at the same time as educating them about the habitat of an endangered species.

Show students the map of the Land of the Tiger at Chessington World of Adventures Resort, as well as the video 'Tiger Rock - 4k On ride POV (Chessington World of Adventures)' that is listed in the resources, so they can see how the roller coaster runs through the tiger's habitat offering visitors different views of the tigers. Discuss what else could be added to this experience to allow people to learn more about the tigers – for example, education boards, places to see the tigers, links to external sites that educate about tigers or competitions to check knowledge.

Students should then think back to the problem of plastic pollution and consider how they might be able to inform people about it using an interactive theme park ride or area. Students should identify six key points that they want people to learn about – this could be about the impact of plastic pollution or the reduce, reuse, recycle message to prevent pollution. They should bear in mind the outcome of the activity.

In groups they should share these ideas and come up with three main points that they believe would educate people about plastic pollution as well as being suitable for inclusion in a theme park ride or area.

Students should work in groups and list the key features of their ride/area. Encourage them to work together to share ideas and be as creative as possible – remember there are three features that they need to include from their earlier thinking. Encourage students to think of ways in which the ethos of recycling can be honoured in the way their ride/area is constructed. For example, they might suggest that the ride contains no plastic at all or is made of reused plastic bottles.

Take it further

If there is time, students could create a map to show what the ride looks like and annotate the key features of it. They could also build a model of the ride and the environment around it, using materials that they have available.

ACTIVITY 17 :
ECOBOT – CREATE A ROBOT FROM PLASTIC

NATIONAL CURRICULUM LINKS IN THIS ACTIVITY

Design and technology

- Develop and communicate design ideas using annotated sketches, detailed plans, 3D and mathematical modelling, oral and digital presentations and computer-based tools.

Science

- Make and record observations and measurements using a range of methods for different investigations; and evaluate the reliability of methods and suggest possible improvements.

SUGGESTED RESOURCES

- Joshua Schofield's profile (pages 190–191)
- Video case study about Joshua Schofield www.youtube.com/watch?v=Tlzw2B4TNIY

EQUIPMENT

- Motor
- Battery pack
- Wires
- Switch
- A piece of cork or 3 cm lump of plasticene
- Assorted plastic products such as drinks cups, small bottles, straws, butter tubs
- Cardboard from recycled packaging
- Rigid items that can be used as legs, e.g. wooden skewers, paperclips, pencils
- Scissors
- Glue
- Sellotape

LEARNING OBJECTIVE

- To understand the components of a simple circuit (cell/battery and motor).
- To design and iteratively develop a robot.
- To test and improve the function of a robot.

INTENDED OUTCOME

Students will make a small robot that is able to move in different directions, demonstrating how an electronic circuit can create motion through vibrations.

ACTIVITY

Introduce students to the idea of creating a robot using the profile and video case study about Joshua Schofield. Joshua, along with colleagues, built a robot called 'NoProbLemo' for a television show called *Robot Wars*. For this activity, students should be given the listed equipment and asked to create a simple robot with a circuit and a vibrating motor that makes it move. Students should be encouraged to be creative in their designs and also to troubleshoot any problems with them.

It is important that students refine their designs by testing and editing. There is no right or wrong way to create the ecobot and through the iterative design process they can make a more efficient robot that can travel in one direction.

Instructions

1. Make the body for your robot using recycled materials. It can be any shape but will need to have room on top of it to attach a circuit with a motor. The rotating part of the motor will need to be able to spin unobstructed.
2. Attach legs to the robot.
3. Create a simple circuit using the motor, battery pack, wires and switch.
4. Put an offset weight on the rotating part of the motor – a piece of cork or lump of plasticene that sticks out more on one side than the other would work well for this.
5. Attach the motor and circuit to your robot, so that it is stable and the weight can easily spin around.
6. Turn on the motor and see how your robot moves. The offset weight should cause the motor to vibrate, making your robot scuttle along the ground.
7. Experiment with the leg positions of your robot. How does your robot move if all the legs are straight? And how does it move if they are at an angle?
8. Experiment with the shape and height of your robot. Can you find a way to make your robot more sturdy or lighter so that it moves more quickly?
9. Keep making adjustments until your robot can glide along with a forwards motion (rather than turning randomly round in circles).
10. Race your classmates! Find out which design is the most effective at making the robot move forwards in a straight line.

ACTIVITY 18 :
WASTE-REMOVAL TECHNOLOGY

NATIONAL CURRICULUM LINKS IN THIS ACTIVITY

Design and technology

- Understand and use the properties of materials and the performance of structural elements to achieve functioning solutions.

Science

- Evidence, and uncertainties in evidence, for additional anthropogenic causes of climate change.

English

- Giving short speeches and presentations, expressing their own ideas and keeping to the point.

SUGGESTED RESOURCES

- Machines with Brains poster (or pages 192–193)
- Sensor list worksheet from www.engineers-making-a-difference.com
- 'The Great Pacific Garbage Patch Explained | Research | The Ocean Cleanup' www.youtube.com/watch?v=0EyaTqezSzs&t=1s

LEARNING OBJECTIVE

- Design an intelligent piece of technology that offers a solution to the problem of waste in the oceans.
- Develop design skills that help to convey ideas.
- Build confidence through presenting your ideas back to the class.

INTENDED OUTCOME

Students need to use the sensor list on the handout sheet to design a piece of technology that can collect plastic from the oceans. Students will learn about sustainability, the Great Pacific garbage patch and electronic sensors.

ACTIVITY

The aim of this activity is for students to design a piece of technology that provides a solution to the problem of waste in the oceans, then present a 60 second pitch of their idea to the class.

Start by watching the video 'The Great Pacific Garbage Patch Explained | Research | The Ocean Cleanup' that is listed in the resources. Then discuss the problem of plastic waste with students – how did it all get there and what are the consequences? Next, read the 'Machines with Brains' poster and discuss how 'smart' robots and machines could help solve the problem of plastic waste. Ask students to design a piece of technology that can remove plastic from the oceans.

Ask students to research and write down the following:

The problem

1. What is the problem?
2. Who is affected by the problem?
3. What causes the problem?
4. What impact does the problem have on the environment?

Can we use technology to solve the problem?

1. Look at the sensor list provided on the downloadable worksheet and consider which sensors might be useful for your device.
2. What other waste-removal devices already exist?
3. Are there any technology devices that you might want to use in conjunction with each other?

Design a solution

1. Come up with a design idea that includes technology that is 'smart' in some way (for example, it might uses sensors or artificial intelligence).
2. Think about how your device will work and where it could be placed. For example, you might need to consider a motion sensor alongside some form of device for collecting or grabbing.
3. Once you have designed your solution, draw the design and add annotations to explain all of the working parts so that we know what it can do.

Elevator pitch

1. You will have 60 seconds to present your idea to the class. You need to describe your product and what it does.
2. Explain the problem and how your product solves it.
3. Explain why you think environmental investors should choose your product.
4. Don't forget to show off your designs!

The class will then vote on whose design they think would be the most effective.

ACTIVITY 19 :
THE OCEANS OF OUTER SPACE

NATIONAL CURRICULUM LINKS IN THIS ACTIVITY

Science

- The magnetic effect of a current, electromagnets, D.C. motors.

Design and technology

- Understand developments in design and technology, its impact on individuals, society and the environment, and the responsibilities of designers, engineers and technologists.

SUGGESTED RESOURCES

- 'Exploring Beyond Our Planet' chapter (pages 194–207)
- Video case study about Professor Michele Dougherty www.youtube.com/watch?v=HYv5_u4NV6A
- 'In Depth | Ganymede – NASA Solar System Exploration' https://solarsystem.nasa.gov/moons/jupiter-moons/ganymede/in-depth/
- 'What Would Standing on Largest Moon Found Ganymede Feel Like?' www.youtube.com/watch?v=0NVPDMnE5DM
- 'What is magnetism?' www.bbc.co.uk/bitesize/topics/z4brd2p/articles/zmw3rwx

LEARNING OBJECTIVE

Identify the properties of a magnetic object and explain how magnetic objects behave in salt water.

INTENDED OUTCOME

Prepare and present a report about the magnetic nature of salt water in an alien ocean.

ACTIVITY

Task One – Space science

Ask students to read the 'Exploring Beyond Our Planet' chapter and consider the challenges scientists face in space exploration. Students should choose the scientist that inspires them the most and think of three questions that they would like to ask them. The scientists who feature in this chapter are: Professor Michele Dougherty, Professor of Space Physics; Jamie Pinnell, Mechanical Engineering Technician; and Dr Veronica Bray Durfey, Spacecraft Operations Engineer and Planetary Scientist.

Task Two – Destination moon

Working in groups, ask students to watch the video 'What Would Standing on Largest Moon Found Ganymede Feel Like?' and look at the webpage 'In Depth | Ganymede – NASA Solar System Exploration' that are both listed in the resources. At the same time, ask students to write a fact file about Ganymede that compares its geographical features with those of Earth.

Introduce students to the space travel project led by Professor Michele Dougherty. At this point, show Professor Dougherty's video case study to introduce the idea of exploring Jupiter. Students will learn the key information about the magnetometer that has been attached to a spacecraft called JUICE (Jupiter Icy moons Explorer), which will land in Jupiter in 2030.

Students should learn what a magnetometer is and how it will be used in space. They should then read Michele's response to the question 'Why do we want to learn about the ocean on Ganymede?'. Discuss her answer as a class to ensure all students understand it.

Task Three – Magnetic oceans

Working in small groups, ask students to read the BBC Bitesize webpage about magnetism that is listed in the resources. Ask them to identify magnetic objects from a list of everyday items that you have chosen, giving reasons to justify their answers.

Students should then create a presentation to advertise the importance of the JUICE project. They should include responses to the following questions:

- What is the purpose of JUICE?
- How does a magnet behave in salt water?
- What is a magnetometer and how will it work in space?
- Why is project JUICE an important design?
- Do you believe scientists should be looking for new and habitable worlds in the future?

Groups should present to the class and compare their answers and ideas to consider the pros and cons of space exploration.

As an extra activity, students could draw a labelled diagram of a magnetometer and explain how it might work in space.

ACTIVITY 20 :
MARTIAN LITTER BUG CONTROL

NATIONAL CURRICULUM LINKS IN THIS ACTIVITY

Science

- Understand that scientific methods and theories develop as earlier explanations are modified to take account of new evidence and ideas, together with the importance of publishing results and peer review.

Design and technology

- Understand developments in design and technology, its impact on individuals, society and the environment, and the responsibilities of designers, engineers and technologists.

SUGGESTED RESOURCES

- Machines with Brains poster (or pages 192–193)
- Dr Veronica Bray Durfey's profile (pages 204–205)
- 'OTD in Space – August 12: Mars Reconnaissance Orbiter Launched' www.youtube.com/watch?v=-GpVb93AF_0
- 'Explore with Perseverance' https://mars.nasa.gov/mars2020/surface-experience/?drive=1222&site=26
- 'The final frontier' www.imperial.ac.uk/Stories/final-frontier/

EQUIPMENT

- A3 paper
- Ruler
- Pencils

LEARNING OBJECTIVE

To identify the challenges of designing a spacecraft in a hostile environment.

INTENDED OUTCOME

Design a new model for a litter-picking robotic arm that can be added to a Mars Rover.

ACTIVITY

Task One – An out-of-this-world tour

Ask students to create a map and a commentary of the solar system, labelling and describing the properties of the following bodies/objects:

Mercury	Mars	Neptune	Earth satellites
Venus	Jupiter	Asteroid Belt	
Earth	Saturn	Sun	
The Moon	Uranus	International Space Station	

Students should research which space bodies have the potential to act as landing stations for future missions. They should also research why it would be useful to have landing stations there, for example, to search for raw materials such as iron ore and water that can be found in the rocks that make up the Asteroid Belt.

Task Two – Alien surfaces

Introduce students to the work of Dr Veronica Bray Durfey (pages 204–205) who is an engineer working on HiRISE – a camera on board the Mars Reconnaissance Orbiter (MRO). HiRISE can provide information on minerals found on Mars from 250 miles above the surface. Dr Bray Durfey analyses the surfaces of planets to consider where spacecraft may land and how they might move and collect data, such as images and rock samples. Students may refer to the video 'OTD in Space – August 12: Mars Reconnaissance Orbiter Launched' that is listed in the resources.

Ask students to describe the surface of Mars using the images captured by HiRISE and list the potential hazards for rovers as they move across the planet. Students can use the 'Explore with Perseverance' webpage listed in the resources to help them.

Task Three – Litter bugs

There have been over 50 missions to or near Mars since the 1960s. This has led to a large amount of litter or space junk being left behind on the surface of Mars. Debris mainly consists of discarded parachutes and heat shields from remote-controlled robots that are based on Mars.

Put students in groups and ask them to design a robotic arm component for a Mars Rover that uses magnets to search the surface and collect any space junk that has been left there. They should consider the challenges that remote control devices may have in space: for example, radiation exposure, excessive heat and cold and the need for a power supply provided by a renewable energy source, such as solar power. Their design will need to be durable, lightweight, magnetic and spacious, and be capable of moving across the surface of Mars. Students may refer to the article 'The final frontier' that is listed in the resources.

Ask the groups to present their designs and vote for the most suitable and creative idea.

EXTRA ACTIVITIES

TIMELINE-RELATED ACTIVITIES

1. Ask students to look at the timeline wallchart and choose their favourite entry. With further research online or in printed books, students should create an information sheet that details the key facts about their chosen entry. This might include:
   - Who were the key people involved?
   - How long did it take them to create their invention?
   - What does the technology look like today?

2. Ask a student to read out loud the timeline entry '1886: First practical car'. Using research online or in printed books, students should create a timeline showing the development of cars from 1886 to the present day. Students should write/draw the timeline and may wish to include entries that predict the future based on current trends, such as electric and self-driving cars.

3. Pick a chapter and explore with students the related entries on the timeline wall chart. From their own knowledge or from further research, ask students if they think any major feats of engineering haven't been included. If so, students should make a case for *why* they should be included.

4. Pick a section of the timeline and write some of the entries out onto cards. Distribute to students and ask them to pick their favourite entry. Why did they pick that particular entry? What do they know about the technology they've picked? Does it impact their life?

POSTER-RELATED ACTIVITIES

1. Introduce students to the concept of farm-free foods by having them read the sections on the 'Farm-Free' poster (or pages 26–27) out loud. How do students feel about the idea of eating lab-grown meat? What is their initial reaction? Ask them to imagine that a restaurant is selling a lab-grown burger and ask them to design a menu that explains the benefits of farm-free foods to customers in a fun and informative way. Encourage them to use images and convincing language.

2. Introduce students to the idea of using drones in farming by looking at the 'Drones' poster (or pages 44–45). Discuss the pros and cons of using drones in this way.

3. Find out how familiar students are with electric car technology. Show them the poster 'Battery-Powered Transport' (or pages 162–163) and ask if anyone knows someone who owns an electric car. Ask students what they think the benefits of electric cars are? And can they think of any negatives? Students can explore this map of electric car charging points: www.edfenergy.com/electric-cars/charging-points. How near to a charging point is your school?

4. Ask students to read about the different types of extended reality (XR) in the poster 'Extending Our Reality' (or pages 178–179). In pairs, ask students to pick either virtual reality, augmented reality or mixed reality. Each pair should create a short presentation on a use for this technology. Depending on the group, you may wish to give ideas such as healthcare, entertainment, manufacturing, etc.

VIDEO-CASE-STUDY-RELATED ACTIVITIES

1. Watch the video case study about Pierre Paslier and Notpla (www.youtube.com/watch?v=DBNIjzg6wFQ). Ask students to write a letter to a business asking them to consider changing the packaging for their products to something more sustainable.

2. Watch the video case study about Navjot Sawhney and the Washing Machine Project (www.youtube.com/watch?v=n23ROHahvtQ). In pairs, have students come up with an idea for another household appliance that could be made simpler for humanitarian and development settings.

3. Watch Joshua Schofield's video where he introduces the robot NoProbLemo (www.youtube.com/watch?v=TIzw2B4TNIY). Ask students to create a fact card for a robot they would create. They should sketch their robot, give it a name and describe three key features. Students should consider how their robot will be engineered – for example, how will it move? Will it have moving parts?

4. Nuclear energy may sound controversial to students – have them watch the video case study about Katriya Sabin (www.youtube.com/watch?v=XdkhLpqR4So) and read Anna Gates' profile (pages 32–35). Students should consider the benefits of nuclear energy and also any associated dangers. Debate/discuss the positive applications of advances in both fusion and fission technologies.

5. The video case study about Dr Clara Michelle Barker (www.youtube.com/watch?v=FTiyX_KmYhY) introduces students to the idea of magnetic levitation. Ask students to create a poster that explains how magnetic levitation works and why it is useful.

6. Georgia Lilley talks about the importance of structural engineering in her video case study (www.youtube.com/watch?v=6AhcPzu-xVk). Ask students to think about the building they are in and the building they live in. Can they name any materials used or elements of the structures? Encourage students to think about form, function and if the buildings were built for specific purposes.

7. Watch the video case study about Dr Natalia Falagán Sama (www.youtube.com/watch?v=LKirzA2bEyg). Ask students to think about foods from supermarkets, such as fruit and vegetables. What packaging is used to keep them fresh? What are the benefits? And the negatives? Ask students to think about what they can do to combat food waste. Using online research, students should create a mini-presentation outlining their top three tips to avoid food waste.

8. Read the timeline entry '1903: First aeroplane' and watch Krystina Pearson-Rampeearee's video case study (www.youtube.com/watch?v=V9DgBb4a3-o). Have students conduct research to fill in the 'gaps' in the timeline between these technologies. What other key events are there in the history of aviation? Have there been any engineering setbacks in this field?

PROFILE-RELATED ACTIVITIES

1. Ask students to choose their favourite profile and imagine that they will have the chance to interview that person. They should think of three questions that they would like to know the answer to. These could be about the engineer's education, their work, their future work, or anything else that the student wants to know!

2. Ask students to list as many different fabric types as they can. Read Dr Benoît Illy's profile (pages 30–31) and encourage a debate on the idea of fast fashion. Students could then research further into the idea of sustainability in fashion.

3. Lots of the engineers in the book give advice for those thinking about joining engineering. Students should look through the book for this advice and collate a 'top tips' information sheet.

4. Read Dr Samantha Micklewright's profile (pages 82–85) where she discusses analysing the gait of a patient. Have students wet their feet and step on a piece of A4 paper. Identify what type of arch each student has and their pronation type – overpronation, neutral and underpronation. Students could research the types of running trainers that they can find for each type – highlight to students that this is a type of design engineering.

5. Engineering is an industry with lots of overlap between sectors. Can students identify themes that run throughout the chapters? Ask them to find profiles that fit an assigned theme – such as sustainability, innovation, battling climate change, and so on.

6. Read Sonny Kombo's profile (pages 152–155) and ask students to list how many different elements he has to consider about an engineering job on the London Underground – utilities, buildings, other transport networks etc. If an engineering job was going to happen at your school, what would the engineers need to consider? Encourage students to think about the area as a whole, for example, could trucks arrive easily by road? What utilities, such as fibre broadband, exist?

7. Read Pavlina Akritas's profile (pages 166–169) and watch her video case study (www.youtube.com/watch?v=LTgdtRfrp3Y). Ask students to consider an environment they have been in that used light in creative ways and how it impacted their mood. One example could be the dimming of a light in a cinema. If available, students can use light prisms or torches with coloured PVC to show the different types of light that can be produced. In groups, ask students to choose a feeling or theme and organise a simple light show to convey it.

8. Read Dr David Trevelyan's profile (pages 170–173). Ask students to create an idea for an audio filter and create a fact card outlining what it would sound like, how they imagine it would be used and what effect they are aiming for.

CAREERS-RELATED ACTIVITIES

1. Ask students what they think of when someone says 'engineering'. Ask them to make a note of this to consider later. Encourage students to explore the contents page of the book to see if any of the chapters sound interesting to them. You may wish to read some of the chapter introductions out loud. Have students read a few of the profiles that interest them and ask them the question again. Has their answer changed?

2. Ask students to watch the video 'Think about a career in engineering' www.youtube.com/watch?v=qMEWfSGytJ0 that tells how some of the engineers in the book embarked on their engineering career. Ask students if they have any questions about the engineering industry and the different routes to it. Help them find answers to these questions.

3. A number of engineers in the book have entered the industry via an apprenticeship. Encourage students to read the profiles of Anna Gates, Katriya Sabin, Samantha Magowan, Manjot Chana, Georgia Lilley, Alan James Proud, Mike Lawton, Jahangir Shah, Bethany Cousins, Todd Downs, Joshua Schofield and Jamie Pinnell and also watch the video case study about Georgia Lilley (www.youtube.com/watch?v=6AhcPzu-xVk). Do any of the apprenticeships that these engineers undertook sound interesting to students? Students could research the appropriate pages on the Government's apprenticeship website:
www.apprenticeships.gov.uk/apprentices/browse-by-interests/engineering-manufacturing#
www.apprenticeships.gov.uk/apprentices/browse-by-interests/construction
to identify courses in areas that interest them. The intention here is to demonstrate the breadth of engineering apprenticeships available.

4. Ask students what GCSEs, and A-levels if appropriate, they think they will need to complete an engineering degree at university. Direct students to read pages 12–13 of the book to get an idea of the different qualifications available.

5. There are lots of different types of engineer. Ask students to name as many as they can and write these on the whiteboard. Students should then read all about the different professions in engineering on pages 10–11 of the book. How many types of engineer did they guess? Can students find an engineer in the book that works in each profession?

6. Watch Dr Clara Michelle Barker's video case study (www.youtube.com/watch?v=FTiyX_KmYhY). Discuss with students why inclusivity is important in the workplace. Ask students to consider how inclusivity impacts on the development of technologies in engineering, for example technology that adapts to a disabled person's needs.

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