Royal Academy of Engineering

THIS IS ENGINEERING

SUSTAINABLE FUTURES

Teacher Guide

Some of the biggest challenges we face stem from how we interact with our environment, and engineering is at the heart of finding sustainable solutions.

Find stories of inspiring engineers and bring the work that they do into your home or classroom.

ABOUT THIS RESOURCE

SOME OF THE BIGGEST CHALLENGES WE FACE STEM FROM HOW WE INTERACT WITH OUR ENVIRONMENT, AND ENGINEERING IS ESSENTIAL TO FINDING SUSTAINABLE SOLUTIONS.

From renewable power to recycling, to making our homes more energy efficient, and tackling how we feed a growing population, engineering is a vital field.

The challenges in this STEM resource invite learners to explore some of these important and pressing problems that society faces, encouraging them to act and think like engineers to find their own solutions to a sustainable innovation design challenge.

Through a series of creative and collaborative challenges, students will develop enquiring minds and teamworking skills and are encouraged to find imaginative approaches to problem-solving, understanding the role STEM-based learning plays in real-world engineering scenarios.

***This is Engineering:* Sustainable Futures** asks young learners to express and share their thoughts and ideas, to be curious, experiment, find their own passions and interests, and to understand, change and make a difference in the world around them.

Tell us what you think...

Take our short survey for a chance to win £500 of robotics/coding equipment for your school.

Scan the QR code on your phone, or go to stemresources.raeng.org.uk/teacher-survey

TEACHER NOTES

This resource is designed to provide practical and contextualised applications where students and teachers can see the role that STEM-based learning plays in real-world engineering scenarios.

Each of the activities and challenges have links across science, maths and design technology. However, some activities will be more heavily weighted towards one subject.

Don't worry! Experience or subject knowledge about engineering and STEM subjects is not required. The resource has been designed to allow students to learn independently and at their own pace, with your support as a facilitator, not a subject expert.

What do I need for the activities in this resource?

We want to make the resource as inclusive and accessible as possible. Although we provide some physical hands-on materials, most of the challenges can be adapted to use items that are easy to find around the house or in most classrooms.

Both the student and teacher guide are available online for free: http://stemresources.raeng.org.uk/this-is-engineering-sustainable-futures

Any teacher who is part of our Connecting STEM Teachers programme will receive hard copies of the resource and the physical materials that are included for free.

Any teachers, anywhere in the UK can join without any cost at any stage.

Find out more about the programme at https://stemresources.raeng.org.uk/connecting-stem-teachers

CHALLENGES

Olivia

The problem with plastics

Investigate how much plastic there is in the products we use every day.

Explore the good and bad of plastics.

The seven types of plastics fact sheet.

Sorting plastics using electrostatic charge.

Waste not, want not

What do we mean by circular and linear economy?

How long does it take to decompose?

Packaging for a circular economy.

Enass

Battery power

Investigate how much charge is left in your batteries.

Make and test your own lemon battery.

Energy efficiency

Discuss accessing electricity.

Make your home more energy efficient.

Halvard

Optimum growing conditions

What are the acid and alkaline levels of your soil?

Do your plants need watering?

Where is the best place for your plants to get the sunlight they need.

Just ripe

Create a test that will tell you how ripe your fruit is.

Competition

Sustainable Futures Innovation Challenge

Find the 'Sustainable Futures Innovation Challenge' booklet at
http://stemresources.raeng.org.uk/this-is-engineering-sustainable-futures

THE *DATAHIVE* GREEN

Every school who attends a Connecting STEM Teachers 'This is Engineering: Sustainable Futures' workshop will receive 15 *DataHive* Greens for their school.

The *DataHive* Green is a device which has multiple sensors to measure:

- Temperature (°C)
- Light (Lux)
- Voltage (V)
- Resistance (Ohm Ω)
- Electrostatic charge

The *DataHive* is used for many of the challenges in this booklet. Keep an eye out for images of the *DataHive*.

The *DataHive* can be powered by a coin cell battery (included) or by connecting it to a computer or laptop using a Micro-USB (not included).

You can view data from the *DataHive* in a number of different ways.

The *DataHive* has a clock, which will automatically set to the correct date and time.

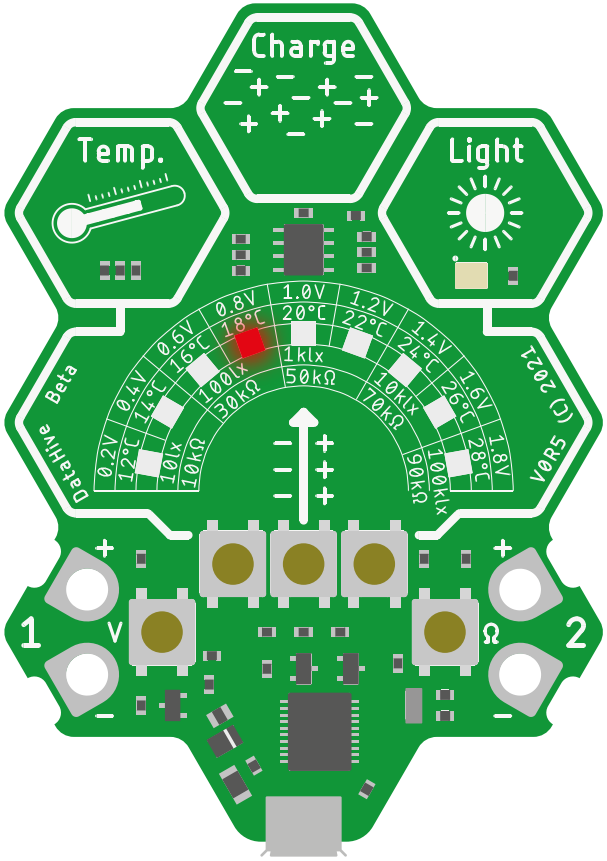
The *DataHive* has many more applications than the activities in htis booklet. We want you and your students to explore, experiment and come up with your own ideas for how it can be used.

DataHive functionality will be updated online. You will find out about updates by visiting data.Redfern.uk.

Contact mindsetsonline.co.uk to find out more about the *DataHive*.

Instant data

You can get an instant reading when you have the coin cell battery in the *DataHive* and press the corresponding button for the different sensors.



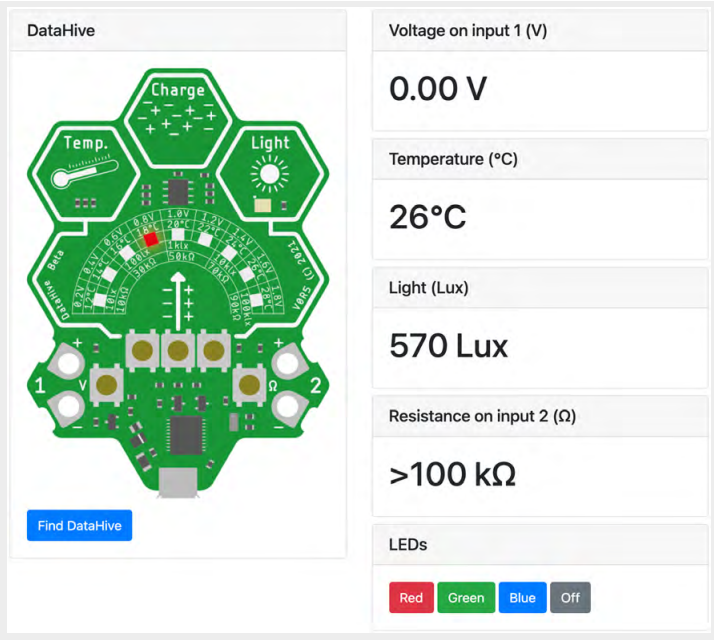
*Coin cell batteries are small and can be easily swallowed. Take care when using these, especially with smaller children.

Live data

Connect your *DataHive* to a computer or laptop using a Micro-USB and visit data.Redfern.uk. Use Chrome or Microsoft Edge.

Click 'Connect' to connect the *DataHive*. You will see live data for each of the five sensors.

You can also turn on all the LED lights red, green or blue using the LED light controller.

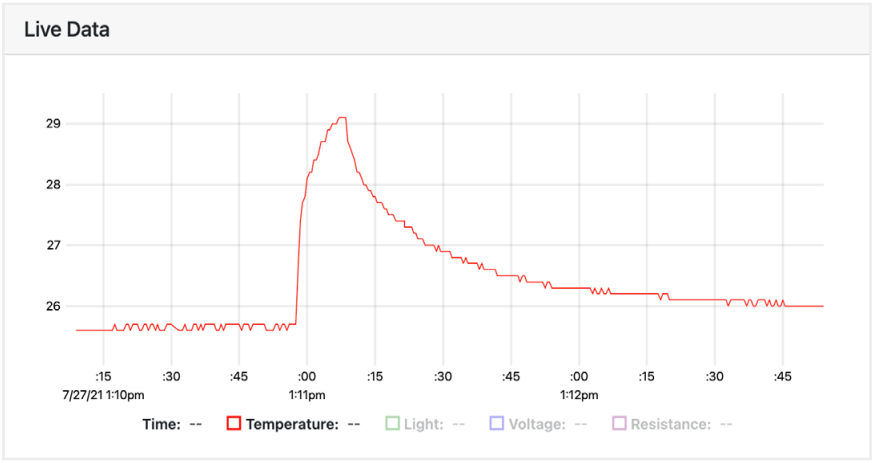


Graphing live data

You will see data displayed live for all the sensors except for the electrostatic charge sensor on a graph.

The x-axis represents time.

You can select which of the four sensors data you would like to view on the graph.



Logging data

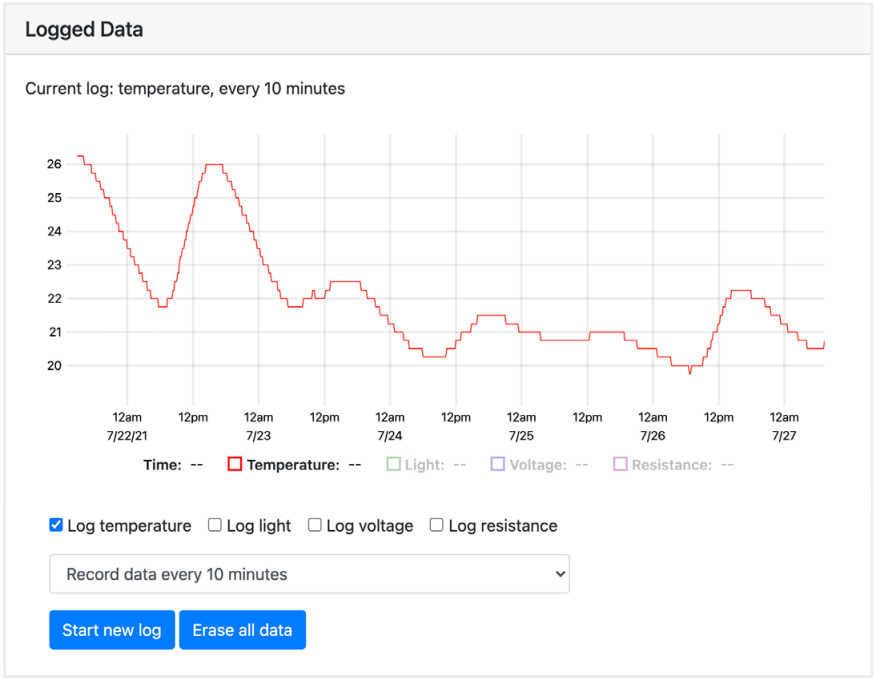
If your *DataHive* is connected to power (either the coin cell battery or connected to a computer or laptop), it can record temperature, light, voltage, and resistance*.

You can view your logged data by connecting to a computer or laptop and visiting data.Redfern.uk.

You can select how regularly you would like to record data. You can also select what data you would like to record.

Once the memory is full, it will start overriding historical data.

You can also delete historical data manually by visiting data.Redfern.uk.



*The *DataHive* will not remember it's settings if it is unplugged from a computer/ laptop and the battery is removed.

CURRICULUM LINKS

The activities and challenges bridge several subjects across science, technology, engineering and mathematics (STEM) curriculum, however for ease of reference, these have been linked to one or two specialisms only.

Age group is given as a guide and activities can be extended or broken down depending on the group.

More information about the national curriculum in England can be found here.
More information about the Scottish Curriculum for Excellence can be found here.
More information about the Curriculum for Wales can be found here.
More information about the Northern Ireland Curriculum can be found here.

Activity	Subject	Age group	Curriculum links
The problem with plastics	*Maths*	9 to 11	I can divide a quantity into a given ratio. I can investigate what happens to quantities when a ratio changes.
	Chemistry	11 to 14	By investigating polymers, I understand that they have different properties.
Waste not, want not	*Design and technology*	9 to 11	I can take appropriate action to ensure conservation of materials and resources, considering the impact of my actions on the environment.
Battery power	*Science*	11 to 14	To begin to understand how batteries work, I can help to build simple chemical cells using readily-available materials which can be used to make an appliance work.
Accessing electricity	*Maths*	9 to 14	I can use technology to collect data, and sort it in a logical, organised and imaginative way. I can analyse and interpret this data.
Optimum growing conditions	*Science*	11 to 14	Having taken part in practical activities to compare the properties of acids and bases, I have demonstrated ways of measuring and adjusting pH and can describe the significance of pH in everyday life.
Just ripe	*Maths*	9 to 14	I can use technology to collect data, and sort it in a logical, organised and imaginative way. I can analyse and interpret this data.
	Science	11 to 14	By exploring colour mixing, I can use my knowledge of the properties of light to show how it can be used in a creative way.
Sustainable Futures Innovation Challenge	*Maths*	9 to 11	I have explored a variety of ways in which data is presented and can ask and answer questions about the information it contains.
	Design and technology	9 to 14	I can analyse how lifestyles can impact on the environment and Earth's resources and can make suggestions about how to live in a more sustainable way.
		9 to 14	I can make suggestions as to how individuals and organisations may use technologies to support sustainability and reduce the impact on our environment.

ENGINEERING HABITS OF MIND

THE ACTIVITIES PRESENTED IN THIS RESOURCE ARE DESIGNED TO BE INTERACTIVE, OPEN-ENDED, ENCOURAGE DISCUSSION AND PROMOTE THE ENGINEERING HABITS OF MIND (EHOM).

The EHoM encourage the use of a pedagogical approach that cultivates problem-solving skills, creativity, making mistakes, reviewing, and planning.

There is no prescriptive teaching method, and it is up to you as a teacher, educator or STEM club leader to decide on which direction you wish to take each activity and where you may wish to spend more time.

Read the full report *Thinking like an engineer* here.

Engineering habits quiz

In the student booklet, we have called the EHoM 'engineering habits' and have included student statements that aim to bring the EHoM to life for young learners.

Students can take the engineering habits quiz to identify what engineering habits they are using, and perhaps ones they would like to work on.

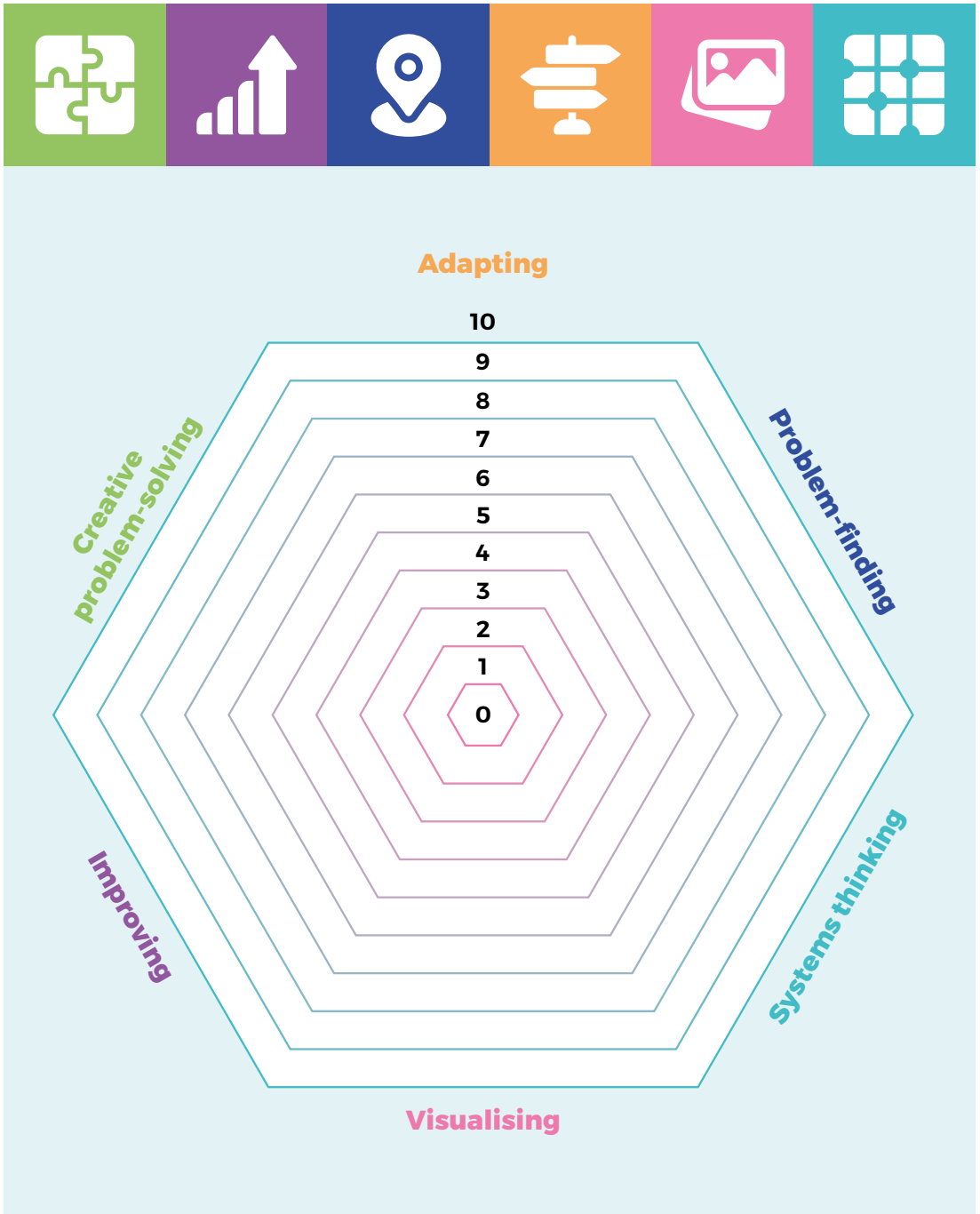
Once students complete the quiz, they can see their results on the EHoM spider diagram and can easily pick out their engineering strengths.

Results are not fixed! We encourage young learners to complete the quiz several times.

They might find that different engineering habits are stronger depending on the type of activity or challenge they are doing.

We have included all the EHoM student statements for both you and young learners for reference and to use in different lessons and activities.

Find the engineering habits quiz on the This is Engineering: Sustainable Futures page on our resource hub.



ENGINEERING HABITS – STUDENT STATEMENTS

I AM GOOD AT...

Creative problem-solving

- Coming up with lots of new and good ideas
- Working successfully in a group
- Taking on board other people's ideas and using them
- Making detailed mind maps
- Thinking first before doing something

Improving

- Making what I have done better
- Experimenting with things just to see what happens
- Working hard and practising to get better, even when it's tricky
- Working out what I need to do to improve
- Sticking at doing something until it's the best it can be

Problem-finding

- Thinking about the world around me and how it could be better
- Finding out why something does not work
- Finding mistakes in mine and other people's work
- Checking and checking again until I am happy
- Asking lots of questions to make sure I understand

Adapting

- Deciding how something could be done differently
- Explaining how well I am doing to my teachers or friends.
- Evaluating how good something is
- Behaving appropriately in different settings
- Sticking up for what I think when talking with other people

Visualising

- Thinking out loud when I am being imaginative
- Making a plan before I start work
- Practising something in my head before doing it for real
- Explaining my ideas to other people so they understand
- Making models to show my ideas

Systems thinking

- Spotting patterns and working out what comes next
- Using ideas from one subject in another
- Putting things together to make something new
- Spotting similarities and differences between things
- Working out the possible consequences of something before they happen

The quiz and student statements are based on EHoM research supported by the Royal Academy of Engineering and published in Hanson, J., Hardman, S., Luke, S., Maunders, P. & Lucas, B. (2018) **Engineering the future: training today's teachers to develop tomorrow's engineers**. London: Royal Academy of Engineering.

STEM BADGES

DIGITAL STEM BADGES REWARD LEARNERS FOR THEIR COMMITMENT TO STEM.

The activities in the student booklet require students to demonstrate their engineering habits.

For each activity they complete from this booklet, we want them to think about which engineering habits they think they have been using and mark it on the STEM badge tracker.

Once they have completed enough of the activities and challenges, they can cash them in for STEM badges.

The badges are digital so they can link them to their online profiles and applications and they won't lose them!

By completing the 'This is Engineering: Sustainable Futures' activities and claiming the badges, your students can quickly progress to Global STEM Awards from STEM Without Borders.

More activities, pathways and information on progression at http://globalstemaward.org.

How do students collect badges?

For each challenge they are working on, students mark up to three engineering habits they have been using on the STEM badge tracker.

Once they have completed three activities, they can come and share what they have been working on with you, their teacher.

Then it's easy. Visit our online platform where you can tell us what challenges your students have completed and share one or two examples of their work with us.

Visit rae.mindsetsonline.co.uk to submit your students' work and apply for badges.

1. Students show you their work.
2. Fill in the form on the website for each student.
3. Attach supporting evidence, e.g. photos or presentation. This is optional, however we always like to see student's work, especially when creative problem solving is involved!
4. Submit forms for approval. You can submit for several students at the same time.
5. Once your badges have been approved, we will send them to you via email to share with your students.

STEM BADGE TRACKER

Name:

THE PROBLEM WITH PLASTICS

WASTE NOT, WANT NOT

BATTERY POWER

ENERGY EFFICIENCY

OPTIMUM GROWING CONDITIONS

JUST RIPE

SOLUTIONS AND FURTHER INVESTIGATION

Challenge one: The problem with plastics

We use plastics in...

Students will come up with their own ideas, and this could be used as a research task, however some ideas to get started with:

PACKAGING

Bubble wrap, cling film, food packaging, crisps.

CONSTRUCTION

Window frames are sometimes made from PVC. Small parts and components are moulded.

ELECTRONICS

Playstation, Xbox, laptops, mobile phones, televisions all use plastic.

HEALTHCARE

Single-use plastic in healthcare is very common as it is so hygienic.

TRANSPORT

Plastic is built into cars, buses and trains, making them lighter and saving fuel.

CLOTHING

Many of our clothes contain plastics, for example polyester, nylon, acrylic and polyamide. Every time we wash our clothes, we are shedding tiny bits of plastic into the ocean.

HEALTH AND BEAUTY PRODUCTS

Microplastics can be found in many of the products that we use such as our makeup, shampoo and facewash.

Time to reflect – the good and the bad

Students will come up with their own ideas, but here are some to get started:

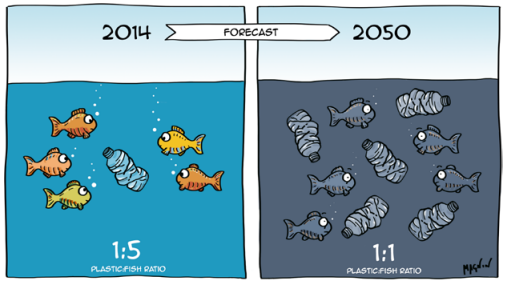
PRO – light, easy to make/mould, cheap, useful for packaging, some plastics can be recycled.
CON – bad for our planet, oceans, animals eat it or get tangled in it, not biodegradable, some are not recyclable.

Some more detailed information around drawbacks of plastics:

- Many plastics are used for a short time or a short first-use cycle.
- 95% of plastic packaging material, worth $80 to $120 billion USD is lost to the economy annually.
- 30% of plastic packaging will never be reused or recycled.
- Approximately 32% of plastic packaging leaks into the environment.

Information taken from reports published by the Ellen Macarthur Foundation.

Time to calculate



In 2014, for every 100 fish, how much plastic was there?
20 pieces of plastic

Stretch and challenge

Take one small sample of the ocean. From 2014 to 2050, predictions show that there will be an additional 200 pieces of plastic.

How much plastic was in that sample in 2014?
50 pieces of plastic in 2014

Sorting plastics

This is the first activity in the booklet that uses the *DataHive*. Using the electrostatic charge sensor, students can start sorting plastics based on their tendency to become positively or negatively charged. This is know as the 'Triboelectric series'.

Materials that usually give up electrons (such as hair) are said to generally become positively charged, and materials that have a tendency to absorb electrons (such as Teflon) are said to become negatively charged. Electrons are said to have a negative charge.

The Triboelectric Series ranks different materials by their tendency to give up or absorb electrons.

Challenge two: Waste not, want not

Waste timeline

Banana/orange peel: two to five weeks (depending on how it's disposed)

Cotton t-shirt: two to five months

Teabag: can be three to six months (depending on the type of tea bag)

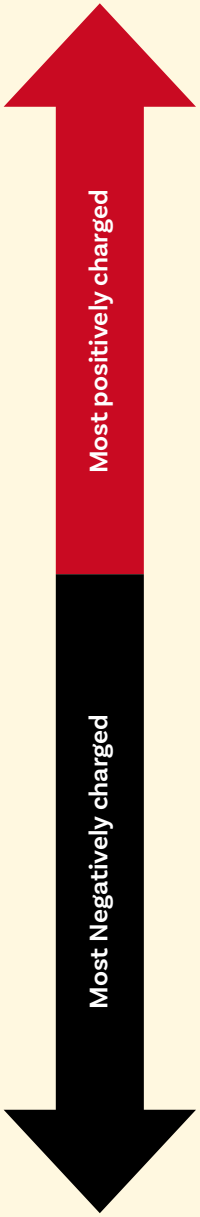
Leather shoe: 25 to 50 years

Battery: 100 years

Wet wipes: 100 years

Plastic bottle: 450 years

THE TRIBOELECTRIC SERIES



Positive +
Hair
Nylon
Glass
Acrylic
Leather
Rabbit fur
Quartz
Mica
Lead
Silk
Aluminium
Paper
Cotton
Wool
Steel
Wood
Amber
Sealing wax
Rubber balloon
Nickel
Copper
Sulfur
Brass
Silver
Rayon
Polyester
Polystyrene
Styrofoam
Plastic wrap
Teflon
Negative –

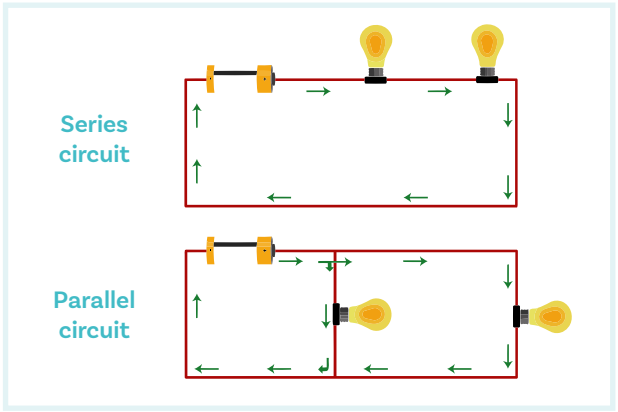
Challenge three: Battery power

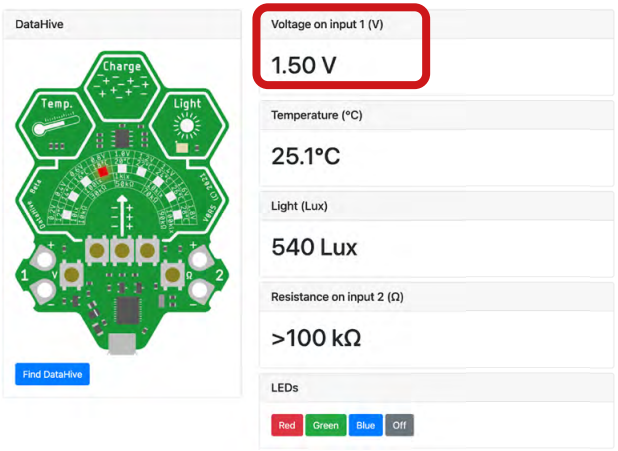
Using the *DataHive* students can measure the voltage of batteries.

An additional challenge would be to create a device that will hold different size batteries so that they can be linked with the *DataHive*.

Taking a voltage reading while the *DataHive* is connected to the computer will give you a more accurate reading. Visit https://data.redfern.uk to see live data.

Learners can also investigate testing the voltage of lemon batteries, trying different fruit and vegetables and wiring them up in series or in parallel.





Challenge four: Accessing electricity

Students can get an instant temperature reading using the *DataHive*.

If they leave the *DataHive* either with the battery in, or connected to a computer or laptop using the Micro-USB, it will record data every minute. They can view this data as a graph by visiting https://data.redfern.uk

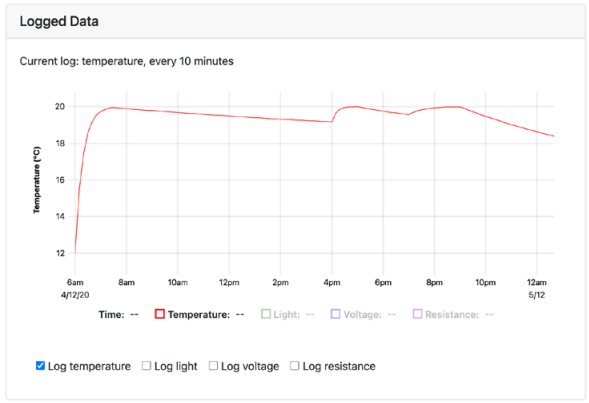
Analysing temperature data

How much does the temperature drop between 9am and 4pm on graph A? ***Approx 3.5°C***

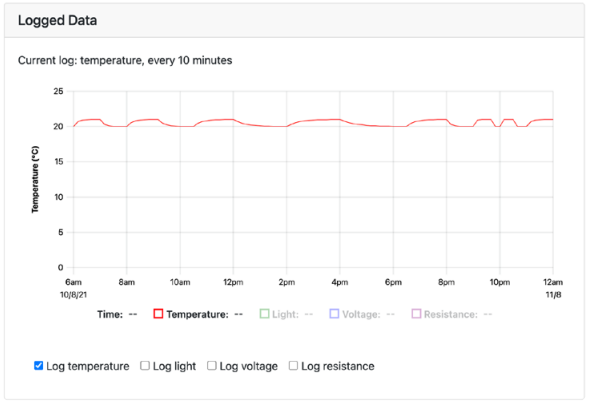
What about the same time on graph B, graph C, and graph D? ***Approx. 1°C, approx 0°C and approx 7.5°C***

Graph A – House D

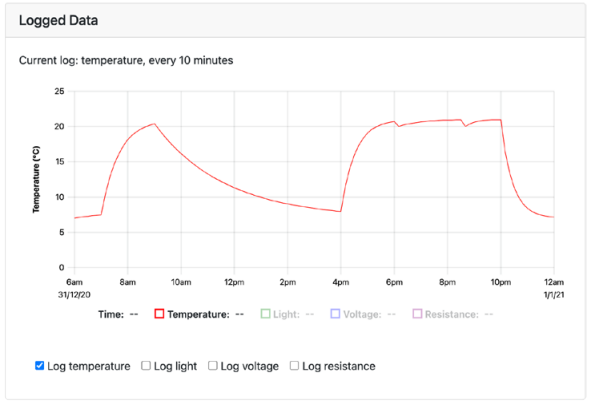
Graph B – House A

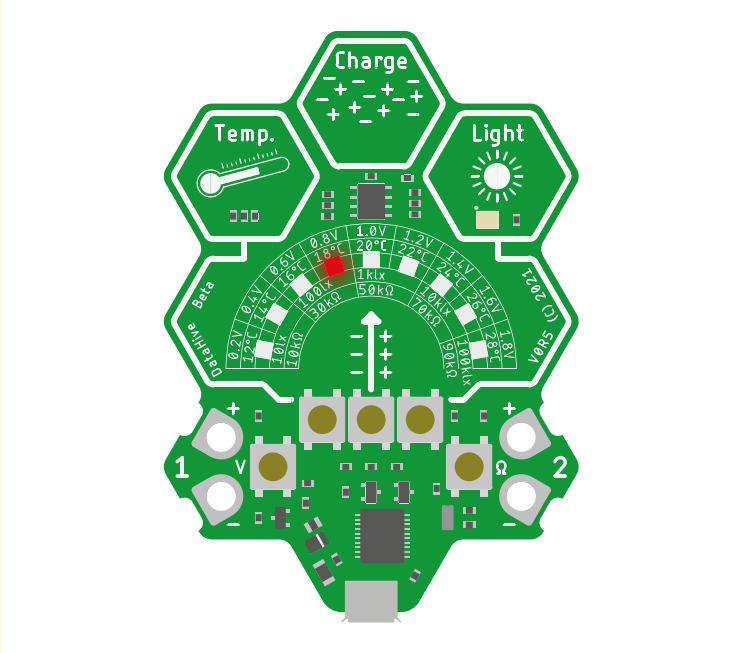


Graph C – House B

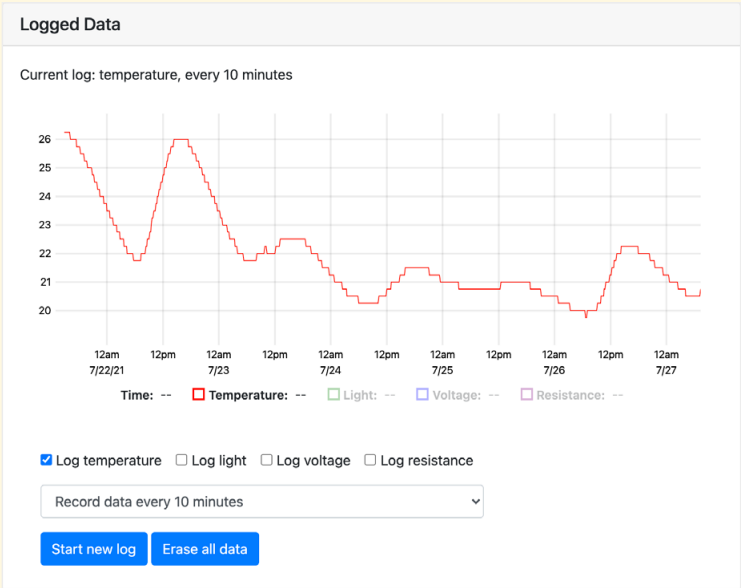


Graph D – House C





Instant temperature reading using the *DataHive*



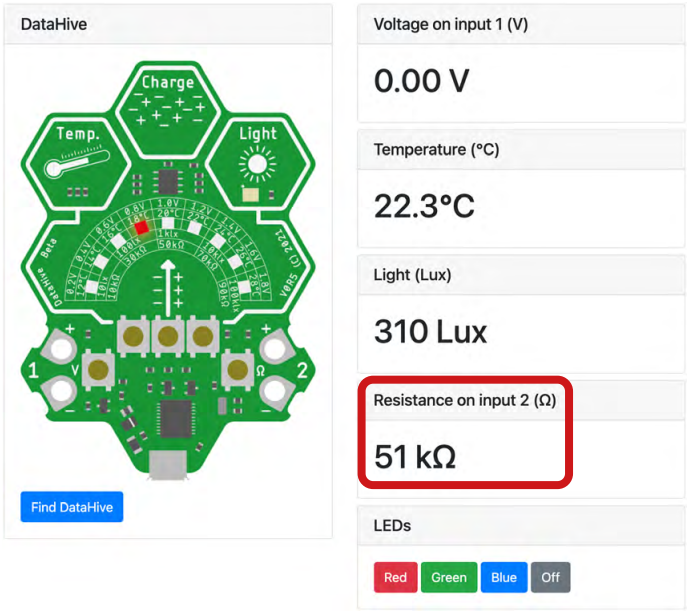
Logged temperature data

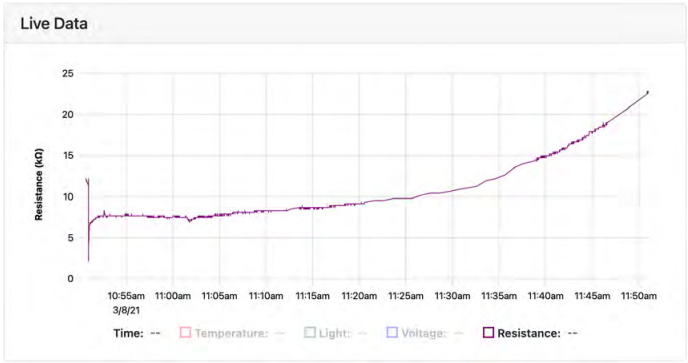
Challenge five: Optimum growing conditions

Grow your own

This challenge asks learners to check the moisture levels of soil that is in their plants using the *DataHive*. They can do this by using the resistance sensor. The greater the resistance, the drier the soil. They can test the conductivity of other materials to experiment with this sensor while doing this challenge.

If the *DataHive* has the battery in it or is connected to a computer or laptop, it will log resistance over time. They can use this to monitor the moisture levels of their plants over time. They can view this data as a graph by visiting https://data.redfern.uk



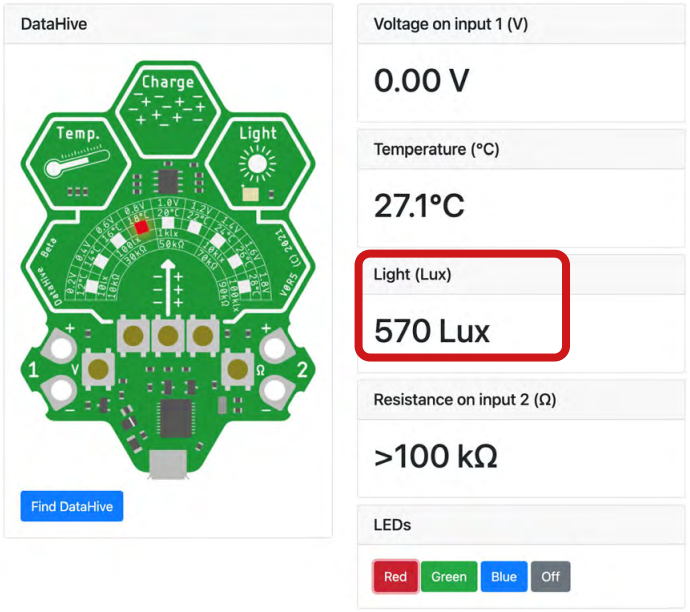


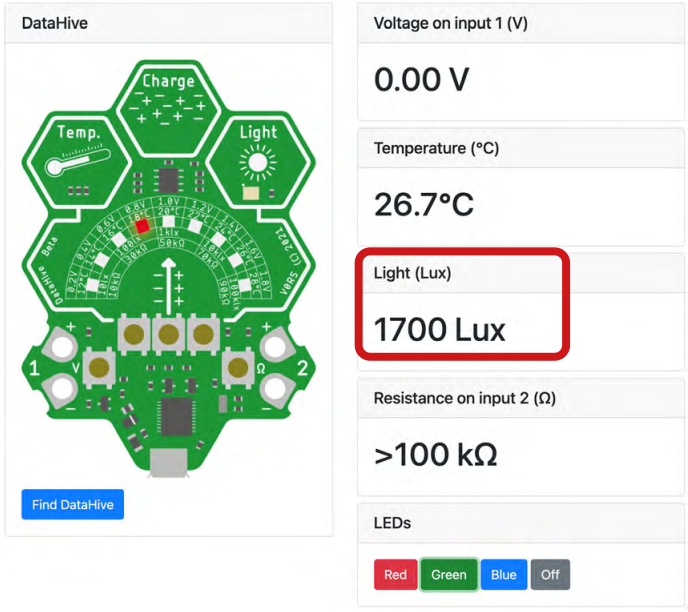
Resistance increasing over time. This shows that moisture levels are decreasing in the soil.

Challenge six: Just ripe

This challenge works in a slightly different way to the others.

- Connect the *DataHive* to a laptop or computer and visit https://data.redfern.uk
- Set up the *DataHive* in a dark place (such as a cardboard box).
- Place a red or green object in front of the *DataHive*.
- Turn on either the red or green LEDs using the controls on the *DataHive* webpage.
- Students should notice a big difference in the light levels depending on which colour LED they have used.





NOTES

Thank you

This STEM teaching and learning resource has been developed by the Royal Academy of Engineering as part of its national **Connecting STEM Teachers (CST)** programme.

CST is a support network for teachers across all STEM subjects ensuring they have the knowledge and confidence to engage a greater number and wider spectrum of school students with STEM. The programme operates across all regions of England, and in Scotland, Wales and Northern Ireland.

The programme, founded by the Royal Academy of Engineering, would not be possible without the generous support of its funders:

Special thanks to our strategic partner Shell, for significant support of the programme.

CST is also generously supported by: Amazon, the Arthur Clements Fund, Boeing, the estate of the late Mr. John Gozzard, the Helsington Foundation and the Royal Air Force.

Royal Academy of Engineering

The Royal Academy of Engineering is harnessing the power of engineering to build a sustainable society and an inclusive economy that works for everyone.

In collaboration with our Fellows and partners, we're growing talent and developing skills for the future, driving innovation and building global partnerships, and influencing policy and engaging the public.

Together we're working to tackle the greatest challenges of our age.

What we do

Talent & diversity

We're growing talent by training, supporting, mentoring and funding the most talented and creative researchers, innovators and leaders from across the engineering profession.

We're developing skills for the future by identifying the challenges of an ever-changing world and developing the skills and approaches we need to build a resilient and diverse engineering profession.

Innovation

We're driving innovation by investing in some of the country's most creative and exciting engineering ideas and businesses.

We're building global partnerships that bring the world's best engineers from industry, entrepreneurship and academia together to collaborate on creative innovations that address the greatest global challenges of our age.

Policy & engagement

We're influencing policy through the National Engineering Policy Centre – providing independent expert support to policymakers on issues of importance.

We're engaging the public by opening their eyes to the wonders of engineering and inspiring young people to become the next generation of engineers.

Royal Academy of Engineering
Prince Philip House
3 Carlton House Terrace
London SW1Y 5DG

Tel: +44 (0)20 7766 0600
www.raeng.org.uk

Registered charity number 293074