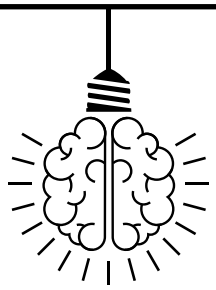
Learning notes

- explore five of the key stories



Discover ideas, activities and opportunities to learn more about the science and technology covered in this edition of Catalyst magazine.

Contents

Curriculum links

(curriculum suitable for age 14 to 19)

Article - Waste heat: a wasted opportunity?

- Energy efficiency
- Energy stores and transfers
- Energy transfers
- Gas pressure and the ideal gas law
- Evaluating the economic and environmental impacts of science

Article – How do you deal with 20 million tonnes of suffocating seaweed?

Working scientifically – scientific thinking, experimental strategies and analysis

Biology

- Photosynthesis and building biomass
- Classification – photosynthetic organisms that are not plants, such as algae
- Ecosystems – nutrient recycling through ecosystems
- Ecosystems – food chains and food webs, plus bioaccumulation
- Ecosystems – positive and negative human interactions with ecosystems

Chemistry – rates of reaction

- Separation techniques
- Applications of chemistry
- Chemical processing

Article - De-carbonising Ammonia: alternatives to the Haber Bosch process?

- Reversible reactions
- Dynamic equilibrium
- Properties of gases
- Le Chatelier's principle
- Environmental issues,CO2 emissions and climate change
- Renewable generation of electricity
- Electrochemistry

Article - Seeing inside the Earth

GCSE science and maths

- sound as a wave
- speed-distance-time

GCSE science and geography

- structure of the earth
- plate tectonics

A-Level geography

- plate tectonics

A-Level physics

- Sound waves, wave amplitude and intensity

Article - Satellites: getting the big picture on Climate Change

GCSE and A-Level Science: physics and chemistry

- radar ranging
- e-m radiation
- wavelength
- frequency
- climate change
- global warming

Article – Choose plant science for sustainable future

- Food security
- Plant productivity
- Photosynthesis
- Careers

Article - To Space and beyond ... with Balloons

Forces, density, Newton's Laws, conservation of momentum, parabolic motion

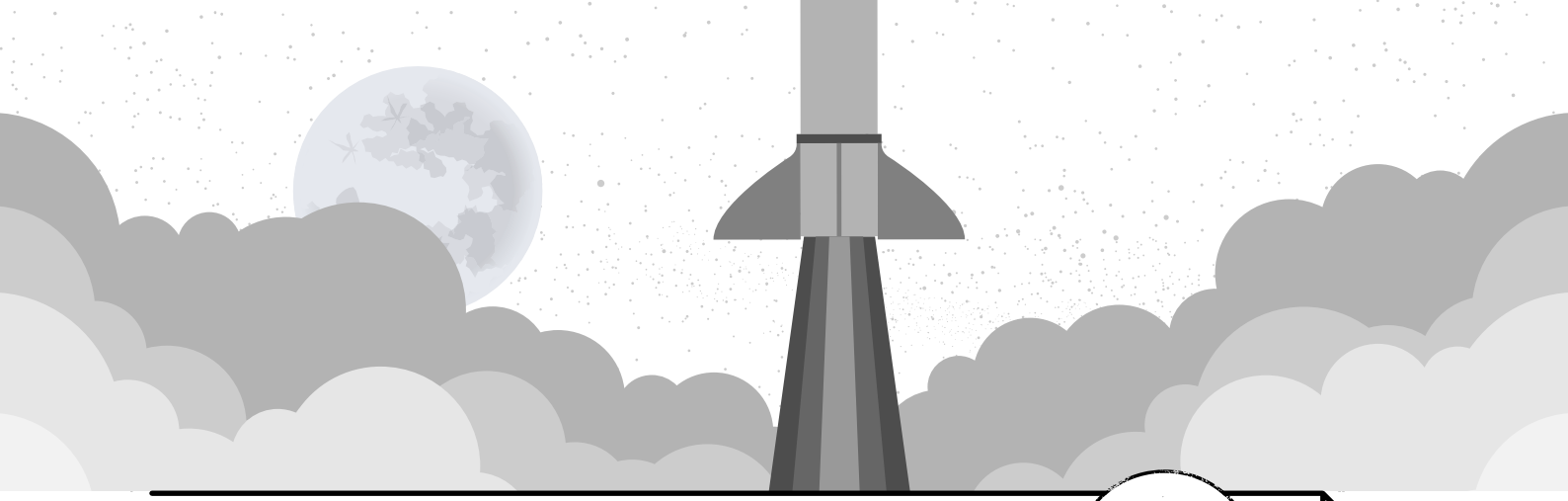
Article - How do cars see?

GCSE/A level: Waves

Trilateration (GPS) this activity helps demonstrate why LIDAR is used and not GPS www.stem.org.uk/resources/elibrary/resource/443553/gps

Article - The Future of Solar Panels

Electricity ,efficiency, compounds



For students

1

Learning notes

Discovering Careers

Main Article: **Reaching for Space: Skyrora, the journey to orbit**

This edition of Catalyst explores what goes on below the earth's crust to satellites that observe us from space and everything in between. Whether they are investigating the future of solar panels, launching balloons into the stratosphere, or observing how plants cope with pathogens. The authors show the passion and enthusiasm they have for their work.

The team at Skyrora give us an insider's view into what it takes to get their dream jobs. What comes through clearly is their determination to succeed, their enjoyment of what they do and their belief that you can achieve anything if you work hard and believe you can do it.

When looking at career choices it is important to not only know what you want to do and how you will get there, but that your chosen career path will give you long lasting enjoyment and satisfaction.

Learning Task:

Here are three questions to consider and discuss with friends, teachers, and family.

1. Which of the articles appealed to you the most?
2. What about it inspired you?
3. Whose career would you most like to have and why?

Take your learning further:

Find out more about the many STEM related careers in this edition of Catalyst or investigate jobs that appeal to you. Here are some suggestions:

- Research the role of the author whose job appeals to you the most. What do you need to do to have a similar career?
- Find out about the organisations the authors work for or have worked for. Can you see yourself working for those organisations?
- Research a career you are interested in and consider the subjects you need to study in school. Do you work towards a place at university or look for an apprenticeship? Is there another route you could take?
- Ask your teacher or STEM Club leader if they could arrange for STEM Ambassadors to visit and give a talk about their work and how they got their jobs. Maybe you could interview them and hone some of your employability skills.
- Think about getting experience related to the role or project you are interested in such as summer placements or volunteer with similar organisations or projects. If you try it out, you'll know if it's for you.

Take every opportunity to research careers and jobs that interest you, ask around and seek advice. The more you find out, the easier it will be to choose the right path for you. And remember, it's ok to change your mind about a career and try something different.

Take your learning further still:

The following websites have information about careers related to the article topics or are useful general careers guidance. Have a look and see what appeals!

Space Careers – from astrophysicists to doctors to oceanographers to systems engineers: spacecareers.uk

Not exactly rocket science - www.chemistryworld.com/careers/not-exactly-rocket-science/5020.article#

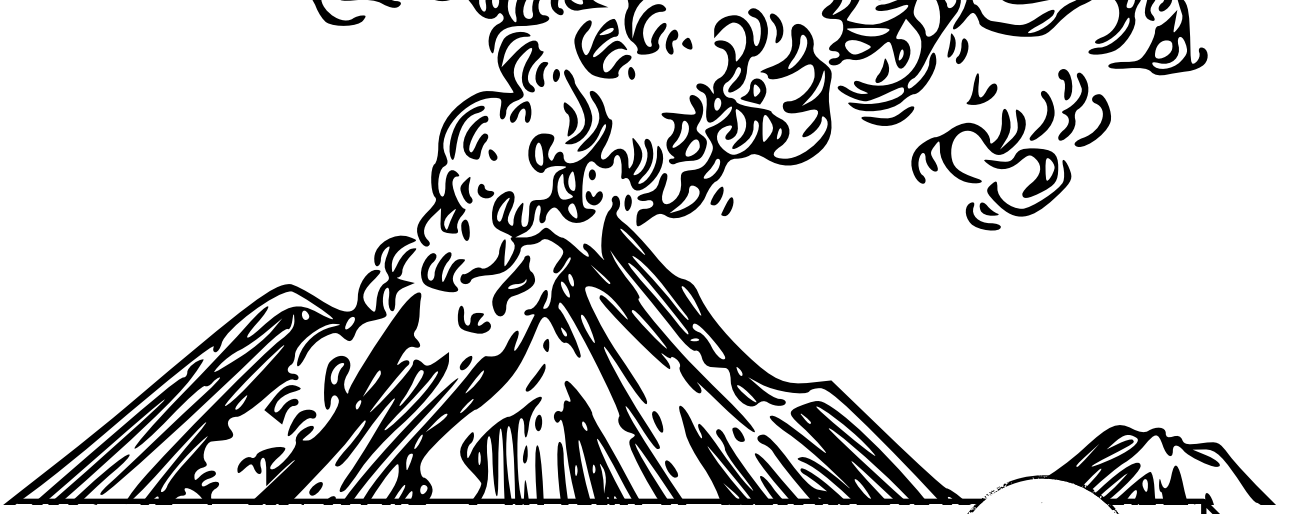
Plant Science, Chartered Institute of Horticulture - www.horticulture.org.uk/grow-careers/plant-science-technology

Marine biology and conservation - www.mcsuk.org/explore-and-discover/career-in-marine-conservation

Careers in renewable energy - www.renewableuk.com/page/Careers

National Careers Service – nationalcareers.service.gov.uk

STEM Learning: www.stem.org.uk/stem-careers



For students and teachers

2

Learning notes

Flowing Solids (aka Silly Putty)

Main Article: **Seeing Inside the Earth**

The article explores how we can "see" the movement of the Earth's mantle, mostly by convection. We traditionally think of convection as a process which occurs only in liquids and gases, but the Earth's mantle is made of solid rock – not liquid magma.

The convecting solid-rock mantle is just one example of a solid which flows over time by the accumulation of tiny motions to produce overall flow, a process called creep (in the mantle this happens by the crystals that make up the rock sliding past one another).

Learning Task:

Silly putty is another example of a solid material which flows through the process of creep. {If you want to make some, we recommend following this recipe: theimaginationtree.com/easy-uk-slime-recipe-contact-lens-solution

Or you can follow this recipe and instructions:

Silly putty recipe:

1) Pour 180 ml PVA glue into a bowl.

2) Mix ½ tsp (2.5ml) of bicarbonate of soda into the glue.

3) (Optionally) mix in any food colouring and glitter as desired.

4) Mix 1½ tbsp (22.5ml) of contact lens solution* into the glue

5) Stir together as the glue forms a putty.

6) Once it all comes together, knead it for a few minutes until its smooth.

When you've finished with your silly putty, and if you want to keep it, it needs to be stored in a plastic, airtight container (e.g. Ziplock bag, Tupperware).

Think about how the putty behaves on different timescales. For example if you throw it against something, versus if you leave it alone for a few minutes-hours? How does this compare to the movement of seismic waves through the deep Earth (travelling at 1000s m per second) vs mantle convection (happening over millions of years)?

You can vary the viscosity (runniness) of the silly putty by adding up to 2tbsp of water at step 3 – how does this affect the behaviour of the putty, especially the timescales of its different behaviours? The mantle is 10^{18} times more viscous than silly putty – how fast might you expect it to flow? [spoiler alert: it's about the speed of fingernail growth]

Take your learning further:

Silly putty, as well as having properties like the solid mantle, behaves similarly to how lava flows (though these are liquids). Try experimenting with how the silly putty flows to explore how lava behaves:

1. Add some rod-shaped sprinkles (vermicelli), or rice, to your silly putty (these represent crystals in a lava).

- When the putty flows, what happens to them?
- How might geoscientists use this when studying volcanoes after the lava has cooled down into solid rock?

2. Use different angles of descent.

- How does the viscosity of the silly putty and the angle of the slope you let it flow down affect how fast the silly putty moves to the bottom?
- What implications does this have for the hazard provided by different volcanoes?

Take your learning further still:

Solid glaciers of ice also flow due to creep, moving by many metres every year. This can be a big problem for scientists drilling ice cores to study past climate signals recorded in the ice, as the flow of the glacier can cause holes to slowly close up while they are being drilled!

3. Look at this map of ice flow in Antarctica (https://earthobservatory.nasa.gov/images/51781/first-map-of-antarcticas-moving-ice).

- Why does it look the way it does?
- Where would you choose to drill ice cores in Antarctica?
- Compare your chosen sites to the map in this article to see where scientists have previously made ice cores (http://www.antarcticglaciers.org/glaciers-and-climate/ice-cores/ice-core-basics). (Ice cores locations in Antarctica).
- Consider why taking ice core samples is important and what we can learn from this valuable data source.

4. During the cold war, America built the Camp Century military base on/in the Greenland ice sheet, which has now been subsumed into the glacier due to its flow. In hundreds of years, we can expect it to pop out the front of the ice sheet.

- What should we do when this happens?
- How would you want to preserve this piece of history?
- What science questions might we be able to answer from looking at the results of this mistake?

To find out more:

There are some great resources and information available to support GSCE and A'Level curriculums: Geography, Physics, Biology, Maths and Careers.

Fire and Ice

This resource presents some real seismic data recorded before a volcanic eruption and allows students to locate some of the resulting earthquakes by use of graphs and maps. Curriculum links include waves, longitudinal and transverse waves, S waves, P waves, disaster relief, earthquake detection. www.stem.org.uk/rx73m9

Explosive Earth

Learn about the volcanic activity that generates earth tremors and the seismologists that measure these tremors to predict future eruptions. This is an article from a previous edition of Catalyst Magazine. www.stem.org.uk/rxcnod

Mount Etna

Discover Mount Etna on the Italian island of Sicily, the biggest and tallest active volcano in Europe and one of the most active in the world. This Catalyst article explores the geology of the volcano, its history and the local habitat surrounding it including how the volcanic conditions create rich fertile soil. www.stem.org.uk/rx324m

Dr Tamsin Mather – volcanologist

A Volcanologist studies the impact of volcanoes on the atmosphere and our planet. Volcanologists often work to try to understand how to better predict eruptions and minimise the effects on people arising from them. They may use computer modelling or satellite imagery and often work on or around volcanoes taking measurements. www.stem.org.uk/rxfra7

Earth Science Podcasts

Produced by the Science and Technology Facilities Council (STFC), these naked Scientist podcasts look at Earth science questions in an accessible and informative way. The podcasts look at: Antarctica; Earthquakes and Ecosystems; Volcanoes, Aeroplanes and our Environment; Hole Punch, Clouds and Making Rain. www.stem.org.uk/rxypz

For teachers

3

Learning notes

Modelling radar or lidar in the classroom

Main Article: **How do cars see?** **Satellites: getting the big picture on Climate Change**

Both radar and lidar use the principle of sending out pulses of electromagnetic radiation, and measuring the time taken for the signal to be received by the sender. Knowing the speed of the waves we can work out the distance to the object. This could be used to measure changes in the sea level or the distance to a pedestrian on a road.

We can model this in the classroom using sonar. An example of its use for satellites is given in this video www.youtube.com/watch?v=ZuedbXIO3vA but this equally applies to the principles used in lidar for self-driving cars.

Learning Task:

Ultrasound sensors, sometimes called motion sensors, are a commonly available piece of hardware, available from educational suppliers. They measure the time taken for pulses of high frequency sound to be reflected from an object. Associated software available with the sensor will then allow settings for time, distance, velocity or acceleration.

To enable students to understand the process of measuring the distance to an object using radar/lidar/sonar it is best for them to use the sensor to measure the time taken for the pulse to be received. By using a value for the speed of sound (approx. 340 ms-1), then can use the speed/distance/time equation to calculate the distance. They must be careful to divide the time taken by two, so they are calculating the distance to the object, rather than the round trip that the pulse has made.

They can create their own surfaces, with books or building blocks, and then compare their calculations to measured distances with a ruler. The sensor should be held in a clamp and moved laterally over the surface so that changes in distance are due to the surface only and not vertical movement of the sensor. An example is given in this video.

Take your learning further:

Very accurate distance measurements are also used in GPS. These activities from the STEM Learning Quantum Ambassador Programme help students understand the principles behind satellite positioning systems.

Quantum Tech Student Activity GPS and Trilateration: www.stem.org.uk/rxfktn

Take your learning further still:

To measure very small changes in distance, interferometry can be used. This principle was used in the Michelson-Morley experiment, measuring the speed of light, in 1887. Now this principle has been used to directly detect gravitational waves. Start from 6:07 in this video to hear how interferometry is used in the Laser Interferometry Gravitational-Wave Observatory (LIGO).

Mini lectures: gravitational waves: www.stem.org.uk/rxeuem

To find out more:

There are some great resources and information available to support GSCE and A'Level curriculums: Geography, Physics, Maths and Careers.

Radar: seeing the unseen

This activity booklet uses the real-life context of air traffic control using radar signals to identify the position of an aeroplane. It provides students with an opportunity to use their knowledge of waves and speed = distance / time to calibrate and calculate the distance a plane is from the radar. www.stem.org.uk/rxh2o8

Anna Hogg - Glaciologist

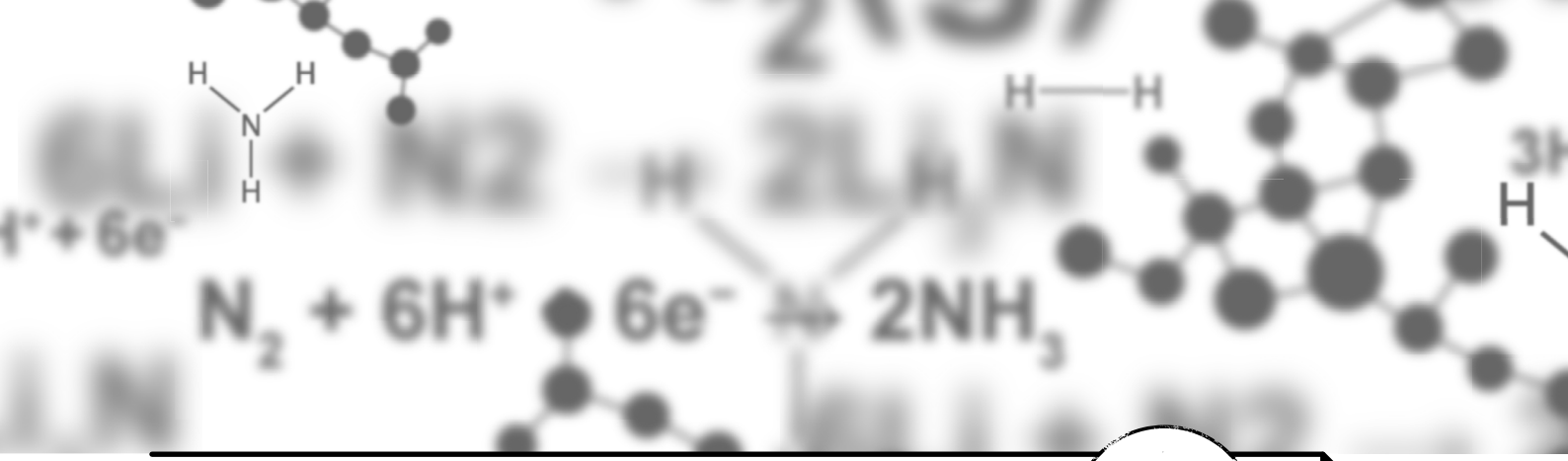
Anna works at the University of Leeds. She uses satellite data to look at glaciers at the poles of the Earth using optical and radar data to track ice movement. She explains how she went to Greenland and Antarctica for field trips to obtain more data for her research. Anna explains how we need to study ice sheets since melting can cause sea levels to rise that will impact many of us across the globe.
www.stem.org.uk/rxfr65

Radar Refractivity: Using Science to Help Forecast Thunderstorms

A Catalyst article explaining how weather forecasts can help keep the public safe in extreme situations by providing advance warnings: for example, airline pilots rely on accurate information about the development of thunderstorms to help them decide which routes might be at risk from lightning or violent downbursts of air. Likewise, people on the ground need timely forecasts of such events as they are vulnerable to flash flooding and hail. This article describes how meteorologists measure the humidity of the atmosphere.
www.stem.org.uk/rxuts

Self-driving cars debate kit

This pack has all you need to facilitate a structured debate on the controversial topic of whether a town centre ought to be for self-driven cars only. The structure shows students how to build a discussion and back up their opinions with facts. This activity is ideal for enhancing useful employability skill sets.
www.stem.org.uk/rxg85w



For teachers

4

Learning notes

Reversible reactions and dynamic equilibria

Main Article: **De-carbonising Ammonia: alternatives to the Haber Bosch process?**

The production of ammonia, as explained in this article, is an important example of a reversible reaction that is used in creating fertilisers. But what is a 'dynamic' equilibrium and how can we explain and model what happens in one? Plus how else can we reduce the environmental impact of ammonia by using it more wisely? The following activities look into the answers to these questions.

Learning Task:

Watch the following video that tries to model a dynamic equilibrium. Think about and answer the following questions.

What does the word dynamic mean in this case? How does it show what happens in a reversible reaction?

Are there any problems with the model used? Are there any situations where it might not show what is happening in a reaction?

Using Video to Illustrate Dynamic Equilibria
suitable for home teaching

Take your learning further:

As well as making ammonia in the 'greenest' process we can, we also need to make sure we apply the best fertiliser in the most efficient way possible so it isn't wasted. Read the following slides that outline how we can use sensors to do this and then make a flow diagram that shows how the sensors work and how they are used to decide where to apply fertiliser in a large field.

Farms, Sensors and Satellites

Take your learning further still:

What sort of careers could you have if specialising in crop protection and how could you help solve global problems in your job? The following videos give an idea what is involved in the role of a research scientist in this area.

Faces of chemistry: crop protection

To find out more:

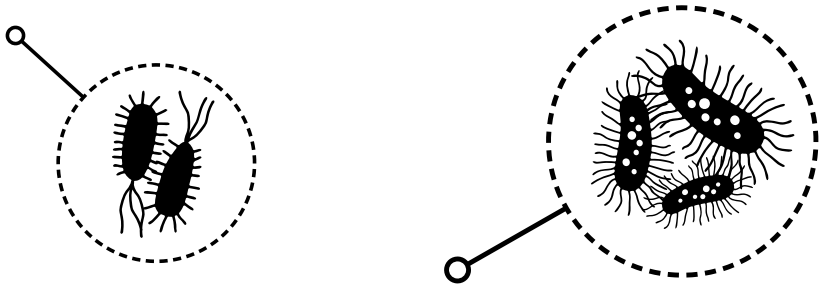
The following resources are available to extend the learning covered by this learning note and the article.

Manufacturing Ammonia - This resource, from the Royal Society of Chemistry 'Challenging Plants' resource pack, is a teacher presentation which provides background information on the industrial processes involved in the manufacture of ammonia. https://www.stem.org.uk/rx346c

Preparation of Ammonium Sulfate - This activity provides an opportunity to prepare a salt which can be used as a fertiliser as an alternative to the preparation of an inorganic salt such as copper (II) sulfate. www.stem.org.uk/rx347g

Making a Fertiliser - In this experiment, students prepare a sample of ammonium sulphate. The ammonium sulphate, an effective fertiliser, is crystallised and dried. Curriculum links include: ammonia, the Haber process, the nitrogen cycle, industrial chemistry, fertilisers. www.stem.org.uk/rx334k

The Properties of Ammonia - In this classic experiment, students heat calcium hydroxide and ammonium chloride in order to produce ammonia. The ammonia produced is tested for pH and solubility in water. Curriculum links include: acids and alkalis, pH, solubility of gasses, Haber process. www.stem.org.uk/rx332n



For teachers and STEM club leaders

5

Learning notes

Doing your own research project

Main Article: **Choose Plant Science For Sustainable Future**

In this article Dr Manisha Sharma talks about how science and scientists, in particular plant science research, can use problem solving to overcome some of the challenges facing our planet. She recommends that young people get research experience if they are thinking of a career in this area or exploring whether such a pathway is for them.

Independent scientific research projects give secondary school students a rich understanding of what it means to be a scientist and of scientific processes. Student-led, open-ended practical projects help students engage with science beyond normal curricular learning.

Use this an opportunity to think about research projects and scientific investigations, to give your students an insight into how science works, as well as developing skills such as decision making, investigation, collaboration and presenting ideas.

Learning Task:

A good starting point is to watch the video, 'From cell to planet in 90 seconds' from the Gatsby Plant Science Education Programme.

- Discuss with the students what they think about the idea that scientific research can 'change the world.'

Take your learning further:

Engage the students in conducting their own scientific research project and involve them in the following:

- Will students work individually or in small groups? Discuss what the pros and cons might be.
- Have the students investigate topics they wish to research and then prepare a reasoned case for the project they will conduct. Considering why have they chosen that project, topic or scientific investigation, what outcomes they expect and any potential difficulties they might encounter.
- Identify key skills, curricular knowledge and employability skills that will be enriched and enhanced through the chosen project. What are the wider implications from developing skill sets.
- Will students conduct the project in classroom lessons, through a STEM Club or extracurricular engagement or through a combination?
- Could the project be part of a scheme such as CREST Awards or Nuffield Research Placement or be entered into a competition, helping to raise the profile, sense of achievement and increase their learning potential?

To find out more:

The following offer students' valuable opportunities to explore potential projects, awards and recognition, careers insight and enhance valuable skill sets. Helping to widen student knowledge of the practical application of science, the processes involved and increase academic potential.

Nuffield Research Placements

Engaging, real-life research or development projects, where talented year 12 (or equivalent) students are placed at the heart of a UK host organisation. They are a fantastic opportunity for students to apply skills and knowledge learned at school while providing a meaningful contribution to the work of researchers and industry professionals. Find out more: www.stem.org.uk/nuffield-research-placements

CREST Awards

The only nationally recognised accreditation scheme for STEM project work for 5-19 year olds. Around 40'000 students in the UK gain CREST Awards every year through investigations and enquiry-based learning, supporting them to solve real-life STEM challenges. Find out more: www.stem.org.uk/cx5dd

IntoBiology

Designed to inform and inspire the next generation of biologists. IntoBiology supports UK biology students aged between 17 and 21, with science news, careers guidance, project ideas and study skills support. It is funded the Gatsby Charitable Foundation and based at the Sainsbury Lab, Cambridge, and Cambridge University Botanic Garden, both part of the University of Cambridge. Find out more: intobiology.org.uk/category/student-projects/

Citizen Science

These are projects where students can engage with data collection and analysis, without having to design the full investigation. From astronomy to zoology, wildlife surveys to exploring diaries from the First World War. The principal behind citizen science is to use the power of collaborative volunteer research to explore or collect huge data sets. These are ones that researchers simply could not manage by themselves, and where computers are not up to the task of analysing. The following are just a few suggestions as there are many citizen science projects available:

BBC: www.bbc.co.uk/programmes/articles/4BZZdHm64S051q2lnZ1Nr7p/citizen-science

The Wildlife Trusts: www.wildlifetrusts.org/citizen-science

Natural History Museum: www.nhm.ac.uk/take-part/citizen-science.html

UKRI: www.ukri.org/our-work/public-engagement/how-we-support-public-engagement/

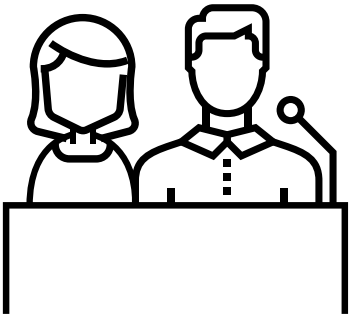
Royal Society Partnership Grants

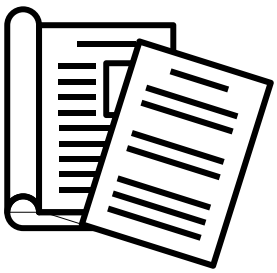
Do you have a great idea for bringing research alive in schools? Partnership Grants of up to £3,000 are available to UK schools and colleges to carry out investigative STEM research projects in their classrooms in partnership with a STEM professional from academia or industry. The grants are designed to help schools and colleges purchase equipment to run these projects. The scheme is open to both primary and secondary schools, including sixth form colleges. Schools outside of the UK are not eligible to apply. Find out more: royalsociety.org/grants-schemes-awards/grants/partnership-grants/

Bring a STEM Ambassador into your classroom

We have a network of over 30,000 inspiring STEM Ambassadors who volunteer their time to inspire the next generation in STEM.

Find out more about how you could bring a STEM Ambassador into your school or college: **www.stem.org.uk/stem-ambassadors**





Thank you

We hope you enjoyed Catalyst, and matching learning notes. If you have any feedback, or ideas for topics you'd like to see covered in future editions, please email:

catalyst@stem.org.uk

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