SUSTAINABLE STORIES AND SOLUTIONS FOR OUR PLANET

A science investigation pack for teachers of 9–11 year olds: Sustainable fuel

CENTRE *for* INDUSTRY EDUCATION COLLABORATION

JM Johnson Matthey
Inspiring science, enhancing life

CONTENTS

INTRODUCTION

The future holds many challenges for young people and our current model of development is placing an increasing burden on the planet. In order to secure the future of children all over the world, we need to make a decisive move towards sustainable development.

This publication will introduce and develop some of the issues and impacts of sustainability for primary aged children aged 9-11 years. All activities are linked to the English National Curriculum for Science, with a focus on the Year 5 programme of study for science content and the full upper key stage two programme of study for working scientifically.

Given that young children will become the next generation of adults; it is important that they are educated about sustainability issues so they can take positive action to help preserve their future in a changing world.

There are many definitions of sustainability. One of the most frequently used is taken from Our Common Future, also known as the Brundtland Report (1987):

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

In simple terms, sustainable development means meeting the needs of all people now – without having a negative impact on the needs of people living in the future.

INTRODUCTORY ACTIVITIES

In the two introductory activities, children consider their own motives behind sustainability as well as develop an awareness of vocabulary linked to current environmental issues. A glossary provides a comprehensive list of all key environmental vocabulary introduced here, then used throughout the activities. Children are encouraged to return to their original ideas to compare their definitions, make any final amendments and reflect upon the learning that has taken place.

MAIN ACTIVITIES

There are five main activities, which introduce children to a range of different challenges within the context of sustainability. These include: energy sources and the sustainability of fuel. The investigative approach provides opportunities for children to explore the varied roles of scientists and engineers in practical ways, allowing the development of key skills including discussion and problem solving. It is intended that children be encouraged to develop their own ideas and questions, methods of recording, conclusions and recommendations. The Questions for thinking included within each activity should be asked as a 'drip-feed' throughout, even though they are written towards the end of each set of teachers' notes.

POWERPOINT PRESENTATIONS

A presentation accompanies each main activity, and contains opportunities for higher order thinking, further discussion, and research. They have been created to help children develop a deeper understanding of our impact on the planet and encourage them to weigh up different opinions and evidence for themselves. Empowering young people to take responsibility for their own future is not only desirable: it is a crucial feature of their education.[1]

Each presentation extends the sustainability message to include wider environmental issues such as the impact of the choices that we make, vehicle emissions and air pollution, an awareness of our carbon footprint, our use of fossil fuels and the development of renewable sources of energy.

The final slides of each presentation contain one company's story to embed the children's learning of sustainability into real life industrial contexts. This is what makes this publication unique in that, for every problem posed within the original main activity, children will learn about one company's solution and find out about how scientists and engineers are striving to find answers to sustainability issues.

In addition to the PowerPoint presentations, teachers may wish to make links with industry via local companies and company websites. STEM Ambassadors are volunteers from a wide range of science, technology, engineering and mathematics related jobs across the UK. They offer their time and enthusiasm and can be found via the STEM Learning website at ***https://www.stem.org.uk/stem-ambassadors***

1 Our Common Future (the Brundtland Report): United Nations through Oxford University Press, 1987.

SUMMARY OF ACTIVITIES

THEME	SUMMARY OF ACTIVITIES	APPROXIMATE TIME TAKEN
Introductory activity 1: Preparatory survey	A survey is carried out by each child to ascertain their thoughts about sustainability as well as their understanding of the impact of their own behaviour in actively bringing about change. Children are encouraged to question family members and compile an overview of current attitudes towards sustainability.	30 minutes (+ 30 minutes discussion)
Introductory activity 2: Environmental vocabulary	Children are challenged to create a 'big-book' style environmental dictionary which will help others in their school to learn about important environmental issues. They suggest definitions for a list of words provided and then refer to the glossary and return to the task to make amendments as they learn more about environmental issues in subsequent activities.	30 minutes (+ 15 mins after each main activity)
A Sustainable Fuel Story	For teacher use only. A quick-start overview of the story of sustainable fuel to support teachers' understanding of how sustainable fuel is created. Not intended for use in the classroom but to enhance the teacher's ability to share this story in a child-friendly way with their class as they carry out the sequence of activities in the classroom.	
1. Electricity to gas	Children observe what happens when an electric current is passed through water, seeing how the combined hydrogen and oxygen in liquid water are released as gases. Developing an understanding that this process is reversible.	30 minutes
2. Main beam	An opportunity to investigate the relationship between the brightness of a bulb and the number of cells in an electric circuit.	1 hour
3. Lumpy challenge	Exploration of three types of sugar dissolving in water, to consider whether there is a relationship between surface area of sugar and rate of dissolving.	1 hour
4. Increasing surface area	Children investigate the properties of different grinding materials to find out which are better at grinding sugar cubes into more finely milled granules or powder.	1–1.5 hours
5. STEM teams	To enhance children's understanding of STEM careers, information about a team of three scientists working on fuel cells is presented in a variety of formats, including game cards, written information, and a map to locate each scientist in the team.	1 hour

SAFETY GUIDANCE

To avoid short circuiting the battery, ensure the carbon electrodes do not touch each other, and that the wires are connected to electrodes before connecting to the battery. Do not leave the cell running for extended lengths of time. Once the children have clearly seen the bubbles, disconnect the wires from the battery before the electrode at the end of the demonstration.

It is important that schools refer to their own health and safety policies when planning, testing and evaluating all practical science activities for themselves. Resources and expectations must be age appropriate and investigations must be supervised by responsible adults at all times.

CLEAPSS is an advisory service providing support in practical science and technology. If at all possible, schools should ensure they have membership with CLEAPSS annually and this will enable them to access important ideas, guidance and safe practical ethics. This will also guide schools in how to correctly 'risk assess' their own practical sessions.

Disclaimer: CIEC assumes no liability with regard to injuries or damage that may occur as a result of using the information contained in the 'Sustainable Stories and Solutions for Our Planet' publication lesson plans.

INTRODUCTORY ACTIVITY 1: PREPARATORY SURVEY

1 HOUR, PLUS 15 MINS AFTER EACH ACTIVITY

A survey is carried out by each child to ascertain their thoughts about sustainability as well as their understanding of the impact of their own behaviour in actively bringing about change. Children are encouraged to question family members and compile an overview of current attitudes towards sustainability.

TYPE OF ENQUIRY

Survey / Researching using secondary sources

OBJECTIVES

Recording data and results of increasing complexity (UKS2 Working Scientifically)

Reporting and presenting findings from enquiries, in oral and written forms such as displays and presentations (UKS2 Working Scientifically)

SCIENCE VOCABULARY

Generations, positive, negative, impact, environment.

RESOURCES PER CHILD

- Photocopy of **Activity Sheet 1:** Survey plus additional copies to take home
- Pencil or pen

PRIOR KNOWLEDGE / EXPERIENCE

Children will have had experience of asking and answering simple questions to gather information or opinion.

ACTIVITY NOTES

Explain to the children that they are each going to complete a short survey which contains questions about looking after the Earth and our environment. Discuss with them that this is not a test, it is just to collect their ideas and that there are no right or wrong answers. Discuss with children that they all might have their own ideas and opinions about the questions they are being asked so that it is very important to answer honestly and with as much detail as they can.

Children should be aware that the teacher can read the questions aloud to them, if appropriate and explain any words or questions they do not understand without providing ideas for their answers. If a child is unable to respond, they should write ***'I do not know'.*** The accuracy of spellings is not important at this stage and there could be a time limit of thirty minutes for completion of the questionnaire, although some children might not need the full amount of time.

Once the survey has been completed, it would be interesting for children to compare their ideas and opinions. Children might also take copies of the survey home for family members to complete and then a wider range of responses can be compared, with a focus on differences and similarities across generations.

Activity Sheet 1: Survey

Complete this survey as honestly as you can. It would be interesting for you to ask family members too. Compare your answers with what other people think.

1. How important do you think it is that we look after the Earth and make sure that it is left in a good state for future generations?

   Why do you think this?

2. What things do you know about that can have a harmful effect on the Earth?

3. What things can we do to help the Earth?

4. What do you do at school/work to help look after the Earth for future generations?

5. What do you do at home to help look after the Earth for future generations?

6. What else do you think you could do?

7. What changes could you make to your own behaviour to help to look after the Earth for future generations?

8. What jobs do you know about where people make a positive impact on the environment?

9. What jobs do you know about where people are causing damage to the environment?

10. If you were Prime Minister, what rule or law would you introduce to help us to look after the Earth?

INTRODUCTORY ACTIVITY 2: ENVIRONMENTAL VOCABULARY

30 MINS + 15 MINS AFTER SUBSEQUENT ACTIVITIES

Children are challenged to create a 'big-book' style environmental dictionary which will help others in their school to learn about important environmental issues. They suggest definitions for a list of words provided and then, later, refer to the **Glossary** and return to the task to make amendments as they learn more about environmental issues in subsequent activities.

TYPE OF ENQUIRY

Grouping and classifying things / Researching using secondary sources

OBJECTIVES

Recording data and results of increasing complexity (UKS2 Working Scientifically)

Reporting and presenting findings from enquiries, in oral and written forms such as displays and presentations (UKS2 Working Scientifically)

SCIENCE VOCABULARY

See full vocabulary list contained in the activity on **Activity Sheet 2**

RESOURCES

per child

- Photocopy of **Activity Sheet 2**: Environmental vocabulary
- Later reference to **Activity Sheet 3**: Glossary
- Pencil or pen

PRIOR KNOWLEDGE / EXPERIENCE

Children will have had experience of asking and answering simple questions to gather information or opinion.

ACTIVITY NOTES

Show children the newspaper headline below.

> Dictionary names 'single-use' as the phrase of the year
>
> There is a rising concern of how much plastic we use once and then throw away. This year has seen huge numbers of businesses pledging to phase out single-use plastics from their operations. Some governments are preparing to ban plastic straws, cotton buds, and other single-use plastics…

Discuss the information provided and describe how, each year, several dictionary companies compile a list of new and popular words that reflect the times we are living in. They have named 'single-use' as the phrase of the year and say that this phrase has been used four times as much over the past twelve months as it has ever before.

Explain to children that they are going to create a 'big-book' style environmental dictionary which will help other children in their school to learn about important environmental issues. There are so many new words and phrases that have appeared in our language over recent years, it is important that young people have a good understanding of what they mean.

Share the list of words on **Activity Sheet 2**. Ask if children can suggest definitions, without carrying out any initial research. They should write their ideas directly onto the sheet under each word provided.

Explain that they will return to the task on completion of the activities in this publication. It will be interesting to see how much additional detail children can include in order to improve their final definitions for the finished dictionary.

Children may also wish to compare their final definitions with those provided in the **Glossary** (**Activity Sheet 3**).

Activity Sheet 2: Environmental Vocabulary

Do you know what the words or phrases in the list below mean? Write your ideas under each word provided. You can return to the task later to make any changes or improvements.

acid rain	electric vehicle	going green	recycle / re-use
carbon footprint	emissions	greenhouse gases	pollution
climate change	environmental impact	landfill	precious metals
degradable	fossil fuels	microplastics	single-use
eco-friendly	global warming	non-renewable	sustainable

Activity Sheet 3: Glossary

acid rain	Water droplets that are acidic due to pollution in the air
carbon footprint	The total amount of carbon dioxide or methane gas you produce per year in your everyday life
climate change	The changes in different environments (temperature, rainfall, cloud cover etc) as a result of global warming
degradable	Able to break down in the environment naturally, or rot away over time
eco-friendly	Least harmful to the environment
electric vehicle	Vehicle with an electric motor powered by electricity from batteries
emissions	Created, given out or flowing from
environmental impact	Any change to the environment, either positive or negative
fossil fuels	A natural, non-renewable fuel, such as coal or gas, formed millions of years ago from the remains of living things
global warming	The processes that cause the average temperature of the Earth to rise
going green	Changing the way you live to help the environment for the better
greenhouse gases	Gases in the air that trap heat from the Sun, so the hot gases stay close to the Earth
landfill	Getting rid of waste material by burying it
microplastics	Very tiny pieces of plastic that pollute the environment
non-renewable	A fixed amount that cannot be replaced
recycle / re-use	To make something new out of something that has been used before To use for the same or a different purpose, something that has been used before
pollution	Any gas, liquid or solid that makes the Earth dirty, poisonous or unhealthy for living things
precious metals	Natural metals of high value that do not react compared to other metals
single-use	Designed to be used once and then thrown away or destroyed
sustainable	To keep it going or available for future generations

A SUSTAINABLE FUEL STORY

This information is for teacher use only. It is not intended to be used in the classroom, but to enhance the teacher's ability to share this story in a child-friendly way with their class as they carry out the sequence of activities in the classroom.

ELECTRICITY TO GAS

Children may already have come across the idea that water is made up of hydrogen and oxygen, but understand little about this, other than coming across the expression H2O. This demonstration is intended to show children that electricity can be used to get hydrogen and oxygen gases from water.

This is a reversible process, of quite a different kind to those children will have come across before (such as getting salt and water back from salty water or 'brine').

Hydrogen fuel cells use hydrogen gas to get electricity. This is a more sustainable process than burning fossil fuels such as natural gas, coal, and oil.

Scientists and engineers across the world are designing and building hydrogen fuel cells to run electric vehicles. These vehicles are better for our planet than those which burn fossil fuels found in petrol and diesel.

MAIN BEAM

Hydrogen fuel cells are very thin so to achieve a high enough voltage to move heavy vehicles such as buses, scientists layer many fuel cells on top of each other, just as children would add additional cells into a circuit in investigating how to make a bulb shine brighter.

LUMPY CHALLENGE AND INCREASING SURFACE AREA

Companies like Johnson Matthey make ingredients called catalysts to add to the layers of fuel cells, to speed up the hydrogen production in the fuel cell. When the catalyst has been made, it is filtered from water, resulting in a 'cake' that is then dried to remove the last of the water. This leaves large lumps of catalyst.

These catalyst lumps need to be ground, or milled, into a very fine powder. This fine powder is made into a 'suspension' in a liquid, which is spread thinly onto fuel cell membranes. The fine powder has a high surface area to speed up the production of hydrogen, in the same way that finer sugar dissolves more quickly or effectively.

STEM TEAMS

Many different STEM professionals are involved in the research, development and production of these fuel cells, and often live in different parts of the country, and potentially different parts of the world. They share their expertise to enable the final products to be used in our electric vehicles.

1. ELECTRICITY TO GAS

30 MINUTES

Children observe what happens when an electric current is passed through water, seeing how the combined hydrogen and oxygen in liquid water are released as gases. Seeing this process and understanding that it is reversible is central to children learning about the work of scientists in making hydrogen fuel cells for electric vehicles.

TYPE OF ENQUIRY

Observing changes over time

OBJECTIVES

Demonstrate that changes of state are reversible changes. (Y5 materials)

Explain that some changes result in the formation of new materials, and that this kind of change is not usually reversible. (Y5 materials)

Make systematic and careful observations (non-statutory)

SCIENCE VOCABULARY

change of state, liquid, gas

RESOURCES

For adult demonstration only

- **Activity Sheet 4**
- PowerPoint presentation: Electricity to gas
- 1ltr transparent jug or beaker
- 15 cm x 15cm card (enough to cover the top of measuring jug)
- 2 carbon rods[2] (fixed to card - see diagram in activity notes)
- 2 crocodile clip wires
- Sticky tape (to secure wires and card)
- 9V zinc chloride PP3 battery[3]

SAFETY GUIDANCE

To avoid short circuiting the battery, ensure the carbon electrodes do not touch each other, and that the wires are connected to electrodes before connecting to the battery. Do not leave the cell running for extended lengths of time. Once the children have clearly seen the bubbles, disconnect the wires from the battery before the electrode at the end of the demonstration.

2 Ensure these are purchased from a reputable science education supplier, such as Philip Harris. At the time of publication, a pack of 10 costs £11.15 +VAT and P&P. Alternatively, borrow the equipment from a local secondary school.

3 39V PP3 batteries must be used, and purchased from a reputable education supplier, such as Philip Harris. Typical price at the time of publication is 65p - £1.00 from a wide range of suppliers.

For comprehensive safety guidance regarding use of batteries in the classroom, the CLEAPSS guidance document Batteries for practical circuit work has up to date advice[4]

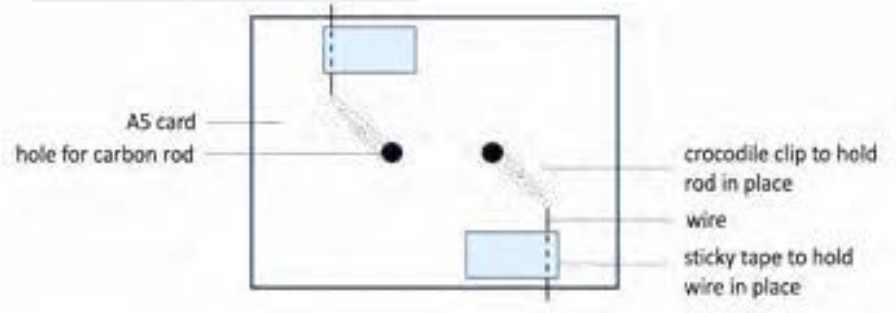
PRIOR KNOWLEDGE/EXPERIENCE

Children should have observed changes in state of water from liquid to gas and been introduced to the idea that this process is reversible (evaporation and condensation). They should also have been introduced to the idea that some changes result in the formation on new materials.

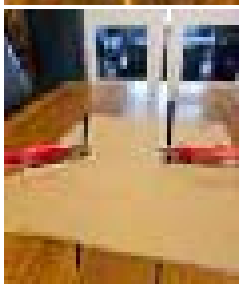
ACTIVITY NOTES

Start by reading the letter from Emily Nesling, scientist at Johnson Matthey (**Activity Sheet 4**) to the class to introduce the Sustainable Fuel challenges.

Carry out the Electricity to gas demonstration. You can construct the equipment before the lesson or with the class watching, as it is quick to assemble. Making your carbon rod holding device:



The demonstration



1. Fill a transparent jug three-quarters full with water.
2. Add the carbon rods through the holes in the card, ensuring they do not touch.
3. Attach a crocodile clip to a carbon rod, securing it with sticky tape to the card.
4. Repeat for the second rod and wire.
5. Attach the crocodile clips at the other end of each wire one to the battery terminal.
6. Observe the rods in the water. Note: You will need to wait 5-10 minutes to see small bubbles forming.

4 For comprehensive safety guidance regarding use of batteries in the classroom, the CLEAPSS guidance document Batteries for practical circuit work has up to date advice.

Children should see bubbles of gas gathering at each of the carbon rods. Oxygen gathers at one rod, and hydrogen gathers at the other.

Use the Electricity to gas presentation to explain to children how the demonstration relates to work scientists and engineers are doing to generate electricity from hydrogen.

Explain that fuel cells go through many stages of computer design and modelling before the final product is made. A prototype, or full-scale model, is made and tested to find out whether the modelled design works, then it is mass manufactured in a factory. Scientists and engineers make decisions together about how successfully tested prototypes will be manufactured on a large scale.

QUESTIONS FOR THINKING

What do you see happening?

- What do you think the bubbles are?
- Why do you think that?
- Are the bubbles different at each rod?
- What states of matter can you see in this activity?
- Where is the electricity coming from?
- Where are the gas bubbles coming from?
- Do you know any other changes of state which are reversible?
- Do you know any irreversible change of state where new materials are made?
- Do you know of any other renewable ways of getting electricity?

USING THE PRESENTATION SLIDES

Explain that fuel cells go through many stages of computer design and modelling before the final product is made. Scientists and engineers then make decisions about how they will be manufactured on a large scale. A prototype, or full-scale model, is made to check the design works, then the design is mass manufactured in a factory.

BACKGROUND INFORMATION

This information is for teacher use only. It is not intended to be used with children, as most of the science is beyond the key stage 2 curriculum.

Electricity can be used to get hydrogen and oxygen gases from water. This is a reversible process, and hydrogen fuel cells use hydrogen gas to generate electricity This is a more sustainable process than burning fossil fuels such as natural gas, coal, and oil.

Scientists and engineers design, test and build fuel cells and their component parts, for use in electric vehicles. Electric vehicles which use electricity generated from sustainable sources, are much better for the environment than those which burn fossil fuels found in petrol and diesel.

The electricity generated from this type of fuel cell is clean which makes it better for our planet than using fossil fuels.

INDUSTRY LINKS AND AMBASSADORS

Ambassadors visiting the classroom could bring examples of the equipment used in the workplace to separate water into hydrogen and oxygen. This process is called 'electrolysis' but this language is not needed in the primary classroom, when more important primary science vocabulary is being introduced to children. Videos and images are an effective way to show items which are too big or unsafe to bring into the classroom.

Video conferencing could also be used so children get to see a scientist working in their lab and have their questions answered.

This electrolysis is safe to carry out in the primary classroom. Visiting lab-based scientists developing hydrogen fuel cell technology, or engineers working at a manufacturing plant would provide an opportunity to see the process of electrolysis in practice in a real-world context.

STEM CAREERS

Dan is a project manager at Johnson Matthey and is responsible for working out how fuel cells can be made in large quantities and whether they have the right machines and equipment.

You can learn more about Dan and STEM careers linked to sustainable fuel in Activity 5.

Activity Sheet 4

Johnson Matthey
Inspiring science, enhancing life

Dear Scientists,

We are designing and making fuel cells that offer a more sustainable way of generating electricity for running electric vehicles.

We have asked your teacher to show you our plan for using water to get electricity. Then we'd like your help with some problems we are facing:

- We have created a fuel cell, but it doesn't generate enough electricity to power the car headlights and make them shine brightly enough. Please can you investigate this to help find a solution?
- To make our fuel cells work better, we have been testing an ingredient used to coat the fuel cells that speeds up electricity generation to run vehicles.

Currently, this ingredient is in big lumps, and we think smaller pieces might help make everything work faster. Could you investigate this please, with ingredients you have access to?

- If you discover that smaller pieces will help, we'd also like some ideas on how to make the big lumps smaller.

We look forward to hearing from you with solutions to our problems.

Yours sincerely,

Emily Nesling

Emily Nesling
Scientist

2. MAIN BEAM

1–1.5 HOURS

Children construct a simple electric circuit with a lightbulb and investigate how they can make the light shine more brightly.

TYPE OF ENQUIRY

Problem solving

Comparative/fair tests

OBJECTIVES

Associate the brightness of a bulb with the number and voltage of cells used in a circuit. (Y6 Electricity)

Planning different types of scientific enquiries to answer questions, including recognising and controlling variables where necessary. (UKS2 Working Scientifically)

SCIENCE VOCABULARY

cell, wire, voltage, bulb

RESOURCES

(per group of four, unless otherwise stated))

- **Activity Sheet 4**
- PowerPoint presentation: Main Beam
- 3 AA 1.5V zinc carbon or zinc chloride batteries
- 3 single AA battery holders
- 4 crocodile clip wires
- Bulb in holder
- Data loggers OR
- Lux meter app on tablet or similar (optional)
- Kitchen roll inner cardboard tube (optional)

SAFETY GUIDANCE

Zinc chloride or zinc carbon batteries must be used.

For comprehensive safety guidance regarding use of batteries in the classroom, the CLEAPSS guidance document Batteries for practical circuit work has up to date advice.

PRIOR KNOWLEDGE/EXPERIENCE

Children should have had some experience of setting up simple practical enquiries, comparative and fair tests.

TOP TIP

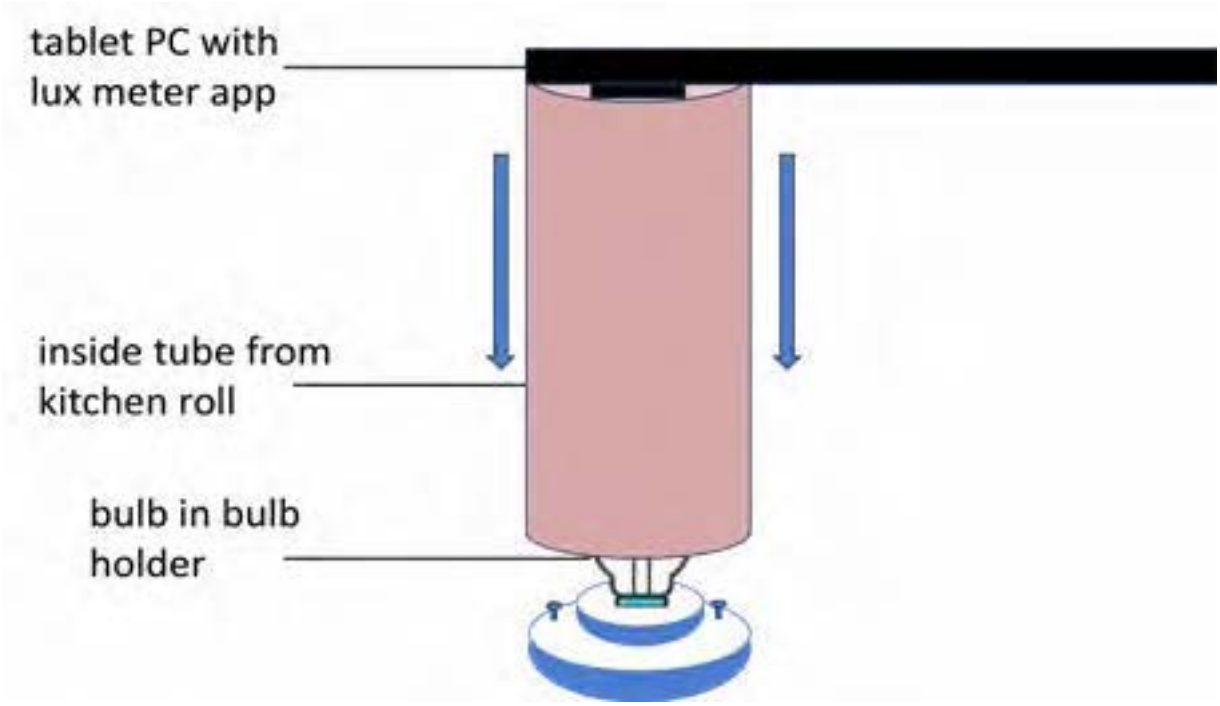
The activity requires children to construct a simple circuit, so depending on the children's confidence in building circuits, it may be worthwhile exploring circuits ahead of the main activity to refresh their memories about how they work.

ACTIVITY NOTES

Re-visit **Activity Sheet 4**; the letter from scientist Emily Nesling, who is developing fuel cells to find more sustainable ways of generating electricity for electric vehicles. The letter asks for children to help Emily find out how she can make a car's headlights shine more brightly.

Children construct a simple circuit containing one AA cell and a bulb. The bulb will light but will not be very bright. Following a period of exploration with one cell, children should be given access to additional 1.5V cells (up to 3 per group – maximum of 4.5v) to continue their investigation to find out if adding more cells to their circuit will increase the brightness of the bulb.

As more cells are added to the circuit, the bulb will be visibly brighter but using data loggers with light sensors or a lux meter app will enable groups to measure the brightness and generate data for use when reporting their findings. Placing the inside tube from a kitchen roll over the bulb ensures an accurate measurement of the light from the bulb without ambient light affecting readings.



The data collected will support children's explanations of their results. Groups can decide how to collect, record and present their observations, measurements and findings.

Use the Main Beam presentation to explain to children that some applications need higher voltages than others, so scientists need to find ways to increase the voltage generated using fuel cells. For instance, vehicles carrying heavier loads such as buses and lorries, require more fuel than vehicles carrying lighter loads such as cars and motorbikes.

Hydrogen fuel cells are very thin, so scientists layer many cells on top of each other to generate higher voltages. Similarly, adding more cells to a circuit increases the brightness of a bulb.

The diagram on the presentation slide shows the various 'slices' which make up a hydrogen fuel cell. All of these 'slices' are extremely thin so that lots of cells can be grouped together and fit inside a car leaving enough room for people.

QUESTIONS FOR THINKING

- How can we get the bulb to shine more brightly?
- How did increasing the voltage/number of cells affect the brightness of the bulb?
- Why did higher voltage/more cells mean the bulb could shine more brightly?
- Why is it important for hydrogen fuel cells to be used instead of burning fossil fuels to get electricity?

INDUSTRY LINKS AND AMBASSADORS

If you can find a scientist with relevant expertise who can visit your classroom, you could ask them to provide some added motivation to your class by setting the initial challenge to the children either in person or by personalising the letter on **Activity Sheet 4**. You could also ask them to bring along some sample fuel cells to show the class, parts of the fuel cell, or images and videos showing the cells in use either in a lab test or in real vehicles.

If you live near to any companies involved in hydrogen fuel cell development or production, you may even be able to arrange a visit to their site to meet the STEM professionals working to develop this exciting technology and see it first-hand.

3. LUMPY CHALLENGE

1 HOURS

Children explore different types of sugar dissolving in water, to discover the relationship between surface area of the sugar and speed of dissolving.

TYPE OF ENQUIRY

Comparative/fair tests

Problem solving

OBJECTIVES

Know that some materials will dissolve in water to form a solution. (Y5 materials)

Compare and group together everyday materials based on their properties. (Y5 materials)

Take measurements, using a range of scientific equipment, with increasing accuracy and precision, taking repeat readings when appropriate. (UKS2 Working Scientifically)

SCIENCE VOCABULARY

liquid, dissolve, solution

RESOURCES

per group of 4, unless otherwise stated

- **Activity Sheet 4**
- 3 transparent cups or similar containers
- Water
- Measuring jug or cylinder (at least 100ml)
- 30-50g granulated sugar
- 30-50g caster sugar
- A few sugar cubes
- Teaspoon
- Stopwatch

TOP TIPS

Children should be given access to a small amount of the different sugars and a teaspoon to enable them to practise measuring their own amounts precisely. They should also be given free access to water, to select the quantities they use.

Each group can use different sized cups/containers, as long as those used within a group are the same.

PRIOR KNOWLEDGE/EXPERIENCE

Children should have had some experience of setting up simple practical enquiries and comparative tests.

If children have misconceptions about the difference between melting and dissolving, try the activity In the Melting Pot from the CIEC A Pinch of Salt publication to enable children to investigate and find the difference for themselves.

ACTIVITY NOTES

Revisit the letter (**Activity Sheet 4**) to present the 'lumpy challenge'.

Tell the children that you are providing different types of sugar to help them plan and carry out this investigation. Ask them to explain the differences between the sugars and plan an investigation to find out the differences in the time taken for each type to dissolve.

Provide support, as appropriate for each group, to ensure they work in a systematic way, keeping variables the same, other than the type of sugar. Wherever possible, give children autonomy and time to make mistakes, leading to deeper learning.

During a plenary discussion discuss how they might improve their investigations if there was time to do so. Point out that this is true for professional scientists too, who refine their investigations in the light of experience. Encourage children to notice a pattern in the relationship between the size of the grain and the speed with which it dissolves.

Ask children to think about how they will share their results with Emily in a clear and concise manner. For example, scientists often replace lengthy prose with photographs, diagrams, tables, charts and graphs.

BACKGROUND INFORMATION

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Companies like Johnson Matthey make ingredients called catalysts to add to the layers of fuel cells, to speed up the hydrogen production in the fuel cell. When the catalyst has been made, it is filtered from water, resulting in a 'cake' that is then dried to remove the last of the water. This leaves large lumps of catalyst.

These catalyst lumps need to be ground, or milled, into a very fine powder. This fine powder is made into a 'suspension' in a liquid, which is spread thinly onto fuel cell membranes. The fine powder has a high surface area to speed up the production of hydrogen, in the same way that finer sugar dissolves more quickly or effectively.

EXTENSION OR HOME-BASED ACTIVITIES

Ask children if they have any experiences with other materials that dissolve, such as salt.

You could ask children to be on the lookout for any other examples of dissolving they come across and report back to the class, perhaps collecting examples on a display or a page in a floor book.

Encourage children to plan and carry out their own dissolving activity at home, perhaps testing out granulated sugar in different liquids like vinegar or sparkling water. An adult could supervise a safe investigation into whether the temperature of a liquid affects how quickly sugar cubes dissolve. Water below 50°C is safe for children to handle.

QUESTIONS FOR THINKING

- Where has the sugar gone?
- How could we get the sugar back?
- What are the benefits of a smaller surface area?
- Does the size of the grains affect the total surface area?

INDUSTRY LINKS AND AMBASSADORS

An ambassador from a local company could initiate the activity, by introducing the challenge to the children and showing them a sample of an unground ingredient of any kind that they would go on to mill into a finer powder (e.g. pigments used in paints). The ambassador could outline their job and explain the skills required to carry out their role, explaining that scientists and engineers in industry often need to find solutions to problems such as this. Finally, the ambassador could discuss the children's results and ask for their recommendations.

STEM CAREERS

Hellen is a senior scientist who works for Johnson Matthey. She uses special computer programs and powerful computers to make models, learn about how ingredients called catalysts work, and how to make better ones. These important ingedients are used to make lots of our everyday products, including fuel cells.

You can learn more about Hellen and STEM careers linked to sustainable fuel in Activity 5.

4. INCREASING SURFACE AREA

1–1.5 HOURS

In this activity, children investigate the properties of different grinding materials to find out which are better at grinding sugar cubes into more finely milled granules or powder.

TYPE OF ENQUIRY

Comparative tests

Problem solving

OBJECTIVES

Compare and group together everyday materials based on their properties. (Y5 materials)

Planning different types of scientific enquiries to answer questions, including recognising and controlling variables where necessary. (UKS2 Working Scientifically)
Taking measurements, using a range of scientific equipment, with increasing accuracy and precision. (UKS2 Working Scientifically)

Reporting and presenting findings from enquiries, including conclusions, casual relationships and explanations of and degree of trust in results. (UKS2 Working Scientifically)

SCIENCE VOCABULARY

material, property, hard, soft, brittle, mass, volume

RESOURCES

- Activity Sheets 5 and 6
- 3 small tough plastic/cardboard containers with lids e.g. 500ml food storage tubs or 40g Pringles containers
- Cup of sugar cubes

Range of spherical grinding materials, hard and soft, and of different sizes e.g. 1 or 2 materials from each of the following:

- hard - marbles, ball bearings, large beads
- soft - polystyrene balls, Smarties, cheese ball crisps 3 foil cases (e.g. mince pie case)
- Funnel (optional)
- 10-25ml measuring cylinder (optional)
- Ice-cube tray (optional)

For the class

- Digital scales (which can measure accurately to the gram)
- **Activity Sheet 4**

TOP TIPS

Use containers with enough space for the grinding materials and sugar cubes to move around.

Ensure containers are durable, as heavier grinding materials will break flimsier containers.

This activity can be very noisy so you may prefer to carry out the shaking outside, in a space away from other classrooms, or even plan for one group at a time to carry out the activity. Ensure anyone with noise sensitivities has ear defenders available to use.

SAFETY GUIDANCE

Ensure lids are tightly sealed before shaking, and that one hand is on the lid during shaking. Extra care should be taken with any materials which are particularly heavy such as ball bearings and marbles.

Spherical items pose a slipping hazard if dropped, so clear away dropped items immediately.

PRIOR KNOWLEDGE/EXPERIENCE

Children will have set up simple practical enquiries and comparative tests. They will have had experience of measuring mass and volume accurately to the nearest 1g or 1ml. They will have created tables of results and used these to create bar charts.

ACTIVITY NOTES

Please note, this is a follow-on activity from the Lumpy Challenge so please complete the activities in sequence to support children's understanding.

Use the letter (**Activity Sheet 4**) to explain to children that scientists would like them to carry out a shake test using sugar cubes and a range of spherical grinding materials. This might include marbles, wooden beads, ball bearings, polystyrene balls, Smarties, and cheese ball crisps. The aim is to break down the lumpy sugar cubes into small pieces, increasing their surface area. The scientists will use this information to decide how best to grind their ingredients.

Give groups time to examine the samples and to discuss the properties of the materials. Ask each group to choose three grinding materials and explain the reasons for their choice of type, quantity, and size of materials. They should aim to select three materials which vary in hardness.

Children plan how they will control as many variables as possible in this comparative test. They can use the Post-It Planning Template (**Activity Sheet 5**) for support in the planning phase by generating a list of variables that they could change and observe/measure. In the case of this investigation, they may think of considering how to control variables such as amount of grinding material used, number of shakes and the duration or method of shaking.

They must also decide how they will measure the amount of ground ingredient produced. One idea to do this is to separate the grinding material from the ingredient, remove any unground ingredient (cubes), collect the ground ingredient, and measure and record its mass (g) or volume (ml).

To measure mass, the ground ingredient can be poured from the container into a foil case and placed on a digital scale which will measure accurately to the nearest gram.

To measure volume, children pour the ground ingredient through a funnel into a measuring cylinder. Results may be recorded in a table, bar chart, or other appropriate format. An example recording sheet is provided in **Activity Sheet 6**.

Groups can repeat the process to test further grinding materials to discover how well each one performs, including observations of the fineness of the ground material. Remind children of their findings from Activity 4 where they investigated different kinds of sugar.

Example data set using 10 sugar cubes and 200 shakes per grinding material:

Grinding material	Mass (g)	Volume (ml)	Ground ingredient coarse or fine?	Observations
none (control)	6	7.5	coarse	Clean sample. Ground sugar is powdery with some lumps.
polystyrene balls	3	3.5	medium	Clean sample. Ground sugar is mostly powdery with a couple of lumps.
cheese ball crisps	-	-	-	Sample heavily contaminated. No visible ground sugar to separate from the fragments of cheese ball crisps.
wooden beads	4	4	coarse	Sample is contaminated with fragments of wood which have chipped off. Ground sugar is powdery with some lumps.
Smarties sweets	5	6	fine	Sample contaminated with fragments of Smarties and difficult to separate sample from grinding material. Ground sugar is powdery
ball bearings	7	10	extremely fine	Clean sample. Ground sugar has the appearance of flour.
marbles	13	15	extremely fine	Clean sample. Ground sugar is powdery.

TOP TIPS

Groups will have tested a variety of grinding materials between them. An ice cube tray or divided paint tray is a good way to 'pool' all the class samples for easy visual comparison.

Polystyrene balls and marbles give the largest measurable difference between the amount of ground material produced and how visually coarse/fine the material is.

Smarties and cheese ball crisps are good materials to use to demonstrate brittleness of certain solids. Grinding materials need to be durable and not break apart during the process. Both the Smarties and the cheese balls start to disintegrate. This contaminates the ground sugar making it unusable.

The cheese balls cushion the impact of the cubes against the side of the container often resulting in no ground material at all to measure.

QUESTIONS FOR THINKING

- Why did some grinding materials work better than others?
- What are the properties needed for a grinding material to be more effective?
- What ingredients do you have at home which may have been ground?
- What other materials might be good at grinding ingredients?
- Are there any ingredients you have at home that you would not want to be ground?
- How are ingredients packaged to stop them being ground?

STEM CAREERS

Ambassadors could explain to the children the methods used in industry to grind materials. Bringing photographs of equipment, pre and post grinding samples of the ground materials and the ceramic beads used for grinding in the plant and laboratory would make the lesson more engaging and memorable.

The ambassadors could respond to questions from the children or give feedback on the quality of the class investigation methods and results.

Emily is a membrane scientist at Johnson Matthey and works in a lab, where she tests catalyst recipes together with new membranes to find out how well they work together in real life.

Emily tries a couple of new catalyst-membrane combinations every month. If Emily is lucky, she finds one combination from about every ten she tries

You can learn more about Emily and STEM careers linked to sustainable fuel in Activity 5.

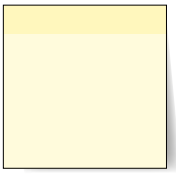
Activity Sheet 5

We could change

We could measure/observe

We will change

We will measure/observe



We will keep these the same...

When I change...

What will happen to?

I think that _____

because _____

Activity Sheet 6

Grinding material	Mass (g) or volume (ml)	Coarse or fine?	Observations

5. TEAMS OF STEM PROFESSIONALS

1.5–2 HOURS

PLUS 4 WEEKS OF OBSERVATION

Children are presented with information about three members of a team of scientists. These three people work in different parts of the country, but the role of each is important to the others, to create new fuel cells for use in vehicles. The information is presented in a variety of formats, including game cards, written information, and a map to locate each scientist in the team, to enhance children's understanding of STEM careers.

OBJECTIVES

To use different contexts to maximise pupils' engagement and motivation to study science[5]

To check that a text makes sense, discussing understanding and exploring the meaning of words in context (UKS2 reading comprehension)

Asking questions to improve understanding (UKS2 reading comprehension)

SCIENCE AND OTHER KEY VOCABULARY

STEM (Science, Technology, Engineering, Maths), collaborate, problem-solving, university, qualification, degree

RESOURCES

(per child or per group of four, unless otherwise stated)

- Set of career cards[6]
- Activity Sheets 7 and 8
- PowerPoint presentation: What job do I do?

ACTIVITY NOTES

Children learn about a 'STEM' team in a science company. They are introduced, via card games, to three scientists who all have different specialisms outlined below. Carry out one or more of these games, depending on the time available. After the game(s), share the presentation, revealing the card 'combination' for each STEM professional.

Once the card games are completed, share **Activity Sheet 7** with the children either on the screen or in hard copy. Read the information together or in groups. Give each group a copy of **Activity Sheet 8**. Ask the children to do any combination of the following:

5 The science curriculum for England (2014)- Page 3, programmes of study: key stages 1 and 2. In several sections of the non-statutory guidance, it is suggested that children work scientifically by considering the work of real scientists (pages 12, 27, 28, 30, 31, 32).

6 Download or purchase from CIEC at £8.15 (inc P&P) for a class set of 7 packs (Sustainable fuel career cards)

- Place the picture card of each person in the box on the map, near where they work.
- Write information in the box on the map about each person and what they do.
- Add information outside the boxes, around the map, about how they work together as a team. Use two different colours to add the information – one colour representing what you know, and one colour representing your thoughts. Think about what connects them, how they might communicate, why they might be based in different parts of the country.

THE CARDS

Each set of cards is based around three employees from a science company called Johnson Matthey. For each employee there are six cards comprising of the following:

- Name and photograph
- Job title and 'What do you do in your job?'
- 'What are your qualifications?' 'What do you need to be good at in your job?'
- 'What did you enjoy at school?'
- 'What are your hobbies?

GAME ONE

The aim is to encourage children to think about what different jobs might entail, and what sort of people might do certain jobs. There are a variety of ways that you could introduce this activity. For example, you could give children the job title cards and ask them to imagine what those jobs might involve before asking them to match the job titles to the photographs and names.

At this point children are likely to point out that it is not possible to tell; it is valuable to give them the opportunity to articulate this idea, as there is much evidence that, despite what we believe, gender and other stereotypes are deeply embedded in all of us from a young age.

You could support them to talk about their understanding by asking questions such as:

- Can you explain why you think that it would be this person?
- Does everyone agree with that?
- What makes you think that?
- Could it be this person?

Ask children what they think that these people might have enjoyed at school. Then look at the 'What did you enjoy at school?' cards and see if it is similar to what they guessed. Can they think of anyone in their class who likes the same things as this person? Do they like any of the same things as these people?

As long as children are engaged and there is a good level of discussion, keep adding cards or people. You may choose to end the session by using the PowerPoint presentation (see notes below) to show children which cards match with which people. However, it is important that children still understand that their suggestions are valid, even if they turn out not to match the reality as there is no way of telling for sure who does which job.

Show children all the 'What do you do in your job?' cards and the 'What did you enjoy at school?' cards. Challenge them to see if they can match them up. (In some cases there are clear links between early interests and current career, in others there are none, so this should give rise to some discussion).

Give out the 'What are your hobbies?' cards. Do they think that older people still like doing the things that they enjoyed when they were at school? Can they match these cards to the ones that they already have?

Use the PowerPoint presentation (see notes below) to see if they have correctly matched the three sets of cards. Again, ensure children understand that all their suggestions are valid as it is impossible to be completely sure which people havewhich hobbies.

GAME TWO

Show children all the 'What do you do in your job?' cards and the 'What did you enjoy at school?' cards. Challenge them to see if they can match them up. (In some cases there are clear links between early interests and current career, in others there are none, so this should give rise to some discussion).

Give out the 'What are your hobbies?' cards. Do they think that older people still like doing the things that they enjoyed when they were at school? Can they match these cards to the ones that they already have?

Use the PowerPoint presentation (see notes below) to see if they have correctly matched the three sets of cards. Again, ensure children understand that all their suggestions are valid as it is impossible to be completely sure which people have which hobbies.

GAME THREE

The cards can be used as a stimulus for children to make their own sets of career cards. Challenges could include:

- Making a set of cards for their future selves. Children could make more than one set; encourage them to think of a range of possibilities. For example, you could discuss that they may have more than one career during their adult lives. If their dream job is not in STEM consider the possibility that there may be a connected STEM career; for example, once they have retired as a premiership footballer, they may consider a job a sports psychologist or nutritionist! The sets of cards made by different children in the class could be used as the basis for a display which encourages children to consider the range of options that are open to them. Encourage children to find out what sorts of choices they will need to make to fulfil some of the ambitions on the cards.
- Making a set of cards for famous scientists both past and present. However, be aware of the danger of these being almost exclusively white, able-bodied males and ensure that people from a diverse range of backgrounds are included. Eg. Stephen Hawkins, Rosalind Franklin, Marie Curie, Maggie Aderin-Pocock and Katherine Johnson. Visit the Famous Scientists website for a diverse representation of important scientists.
- Making a set of cards for scientists and engineers that they have met. If they have been on a Children Challenging Industry visit this might include people from the industry that they visited. Alternatively, it could include visitors into school or family members or family friends. If there is the opportunity, children could interview potential subjects or, if this is not possible, allow them to use artistic license to fill in missing facts such as what their subject liked doing at school.

QUESTIONS FOR THINKING

Questions have been added to the appropriate sections above. In addition, you may like to ask:

- Do you know anyone who has a job using science? Is it different to these jobs?
- Do you know anyone who has gone to university? What did they study? What job do they do now?
- What do you know about going to university?
- Some people become apprentices instead of going to university. Do you know what an apprentice is? Do you know how this is different to going to university.

INDUSTRY LINKS AND AMBASSADORS

This activity provides a good opportunity to link with a broad range of STEM careers in industry. If possible, connect with ambassadors who have been to university as well as others who are or have been apprentices, and ask them to share reasons for their choices and what their time as an apprentice or student was like, e.g. 'a typical day' as a student/apprentice.

Request STEM ambassadors well in advance, who can visit your classrooms in person or virtually to discuss their experiences.

STEM CAREERS

The aim of this activity is to introduce children to 'scientists' who have developed their careers in different directions. Johnson Matthey employs a high number of chemists, but as with many science-based companies, employs other scientists (such as Hellen, a physicist) and a wide range of engineers (chemical, mechanical, electrical etc).

Activity Sheet 7: Teams of STEM Professionals

Hellen is a senior scientist who works for Johnson Matthey in Billingham, Northeast of England. She uses special computer programs and powerful computers to make models, learn about how ingredients called catalysts work, and how to make better ones. These important ingredients are used to make lots of our everyday products, including fuel cells. Hellen works with other scientists to improve or discover new catalysts that help the environment by making fuel and air cleaner. Hellen creates many models for these ingredients every week. Every few months, she finds a really good model and sends this to scientists who	Catalysts are ingredients used in fuel cells and other things. Catalysts are powders when first made.
Emily is a membrane scientist and works in Swindon in the Southwest of England, about 260 miles from Hellen. Emily works in a lab, where she tests Hellen's recipes together with new membranes to find out how well they work together in real life. Emilyn tries a couple of new catalyst-membrane combinations every month. If Emily is lucky, she finds one combination from about every ten that Hellen sends her. Emily is then very excited about this, and sends the design that works to Dan.	Membranes are special kinds of filters, that are thin, soft and flexible (bendy).
Dan is a project manager and he works in Royston in the Southeast of England, about 120 miles from Emily. As a product manager, Dan is responsible for working out whether the combination of Emily's membrane and Hellen's catalyst recipe can be made in large quantities (thousands of kilogrammes a year!) and whether they have the right machines and equipment to combine the ingredients and make millions of fuel cell products. Dan tries two new recipes a year and then other people in the team help decide whether they are going to make it, as they need to build a lot of new equipment which takes 2 - 3 years to do. Only two new products will be made every year.	Fuel cells are made up of many layers of catalyst and membrane. The very fine catalyst powder is mixed with a liquid and looks like ink, so it can be spread over the membrane.

Activity Sheet 8: STEM Team Map

CIEC offers support for the teaching of science across the primary age range and beyond. This support includes CPD programmes, bespoke in-school CPD, interactive websites for teachers to use with their pupils, and a wide range of downloadable resources which encourage collaborative, practical problem solving. For more information, please visit our website:

www.ciec.org.uk

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