Royal Academy of Engineering

THIS IS ENGINEERING

Teacher guide

Exploring the vital role engineers play in responding to a global pandemic

ENGINEERING *IN A* PANDEMIC

ABOUT THIS RESOURCE

The engineering community plays a vital role in our daily lives and engineers were essential in responding to the COVID-19 pandemic.

While the pandemic has had devastating global effects, the engineering community worked together to quickly respond to the sudden demands of coronavirus, even finding opportunities for positive change.

Engineers have created emergency ventilators, diagnostic tests and manufacturing methods, helped increase hospital capacity, ensured that vulnerable people can safely get supplies and helped us all stay in touch with friends and family while social distancing.

Challenges in this STEM resource include building your own virus, exploring what happens in an outbreak, investigating lateral flow tests, designing and developing social distancing tools, testing and trialling different types of surgical masks and investigating the tech that has helped us manage the outbreak.

In response to COVID-19 and the changing needs of schools in this academic year, schools will be sent individual packs for students containing materials needed for the different challenges. This resource is available to download for free on the Academy website and our STEM resources hub. It will also be part of our STEM at home series.

This resource is available to download for free at https://stemresources.raeng.org.uk/engineeringin-a-pandemic/

TEACHER NOTES

This resource is designed to provide practical and contextualised tasks that demonstrate 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 more than others.

Don't worry! Experience, or subject knowledge around engineering or any STEM subject 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 and not a subject expert.

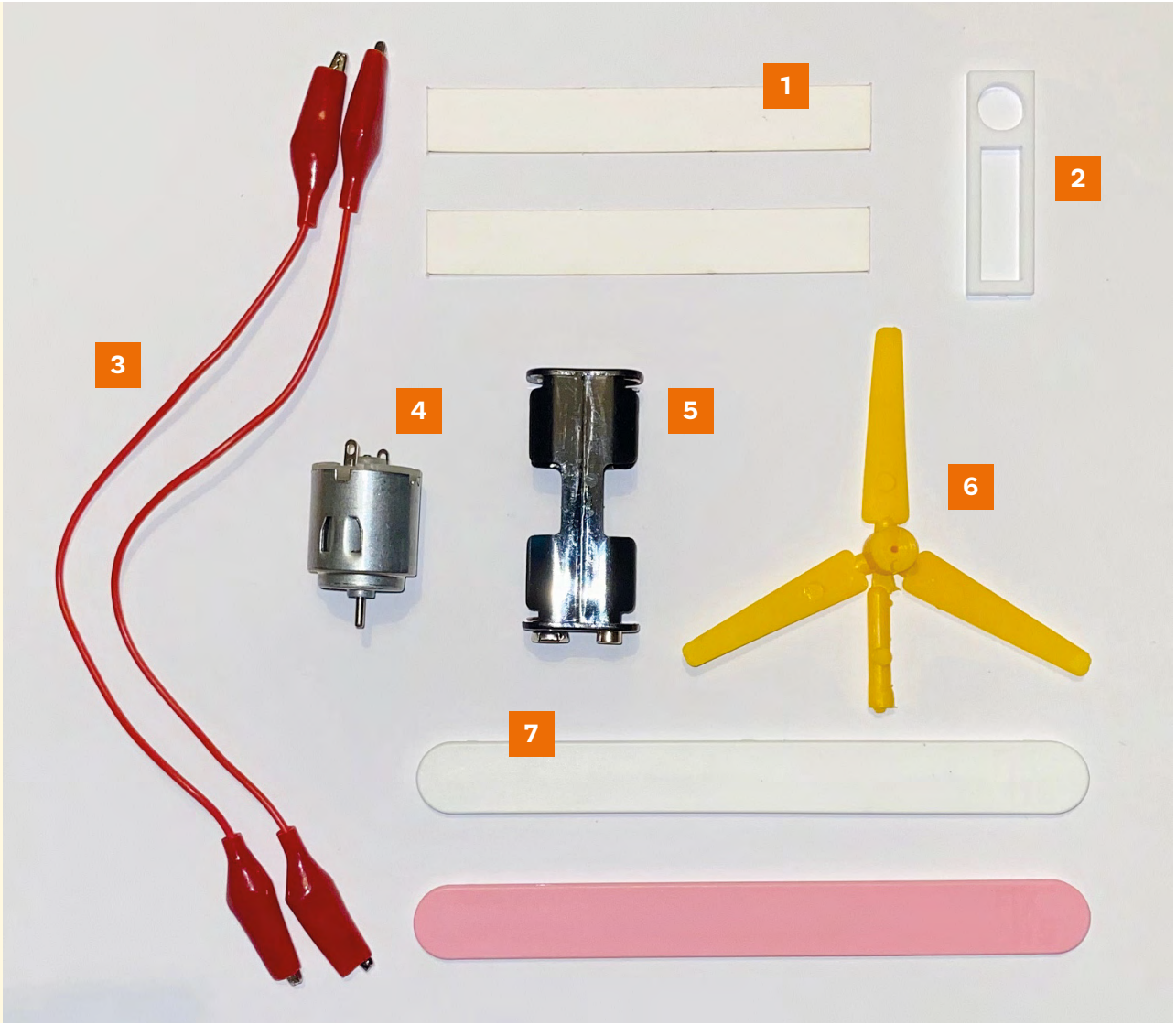
STEM at home

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

WHAT'S IN THE PACK

1. One sheet of chromatography paper to be split two per student
2. Chromatography paper holder
3. Croc leads
4. Motor
5. Battery pack (batteries not included)
6. Fan blades
7. Two moulding sticks

All of these materials can be purchased at:
https://mindsetsonline.co.uk



CHOOSE YOUR CHALLENGE

Setting the scene
What is a pandemic

Spotlight
Innovation in a crisis

Challenge one
Post-pandemic world

Challenge two
Virus BioArt

Challenge three
Outbreak

Spotlight
Vaccine factory-in-a-box

Challenge four
Testing, testing, testing...

Challenge five
Block the way

Spotlight
Tech4 pandemics

Challenge six
Weird and wonderful face masks

Challenge seven
Respirator challenge

CURRICULUM LINKS

The activities and challenges bridge several subjects across the science, technology, engineering, arts and mathematics (STEAM) 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
Post-pandemic world: Design challenge	**Design technology**	9 to 14	I explore and discover engineering disciplines and can create solutions to a given problem.
Virus BioArt	**Science**	9 to 14	I understand that viruses are constantly evolving and can cause different diseases in the body.
	Art	9 to 14	I can develop and communicate my ideas, demonstrating imagination and presenting at least one possible solution to a design problem.
	Design technology	9 to 14	I can recognise and use more complex materials and take into account their properties.
Outbreak	**Maths**	11 to 14	I can display data in a clear way using a suitable scale by choosing appropriately from an extended range of tables, charts, diagrams and graphs.
	Maths	9 to 11	Through exploring number patterns, I can recognise and continue simple number sequences and can explain the rule I have applied.
Testing, testing, testing	**Science**	11 to 14	I have participated in practical activities to separate simple mixtures of substances and can relate my findings to my everyday experience.
Block the way	**Science**	9 to 14	I can describe how vaccines provide protection and how vaccination programmes protect a population.
Weird and wonderful facemasks	**Design technology**	9 to 11	I can investigate how product design and development have been influenced by changing lifestyles.
Respirator challenge	**Design technology**	9 to 14	I can recognise basic properties and uses for a variety of materials and can discuss which ones are most suitable for a given task.

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.

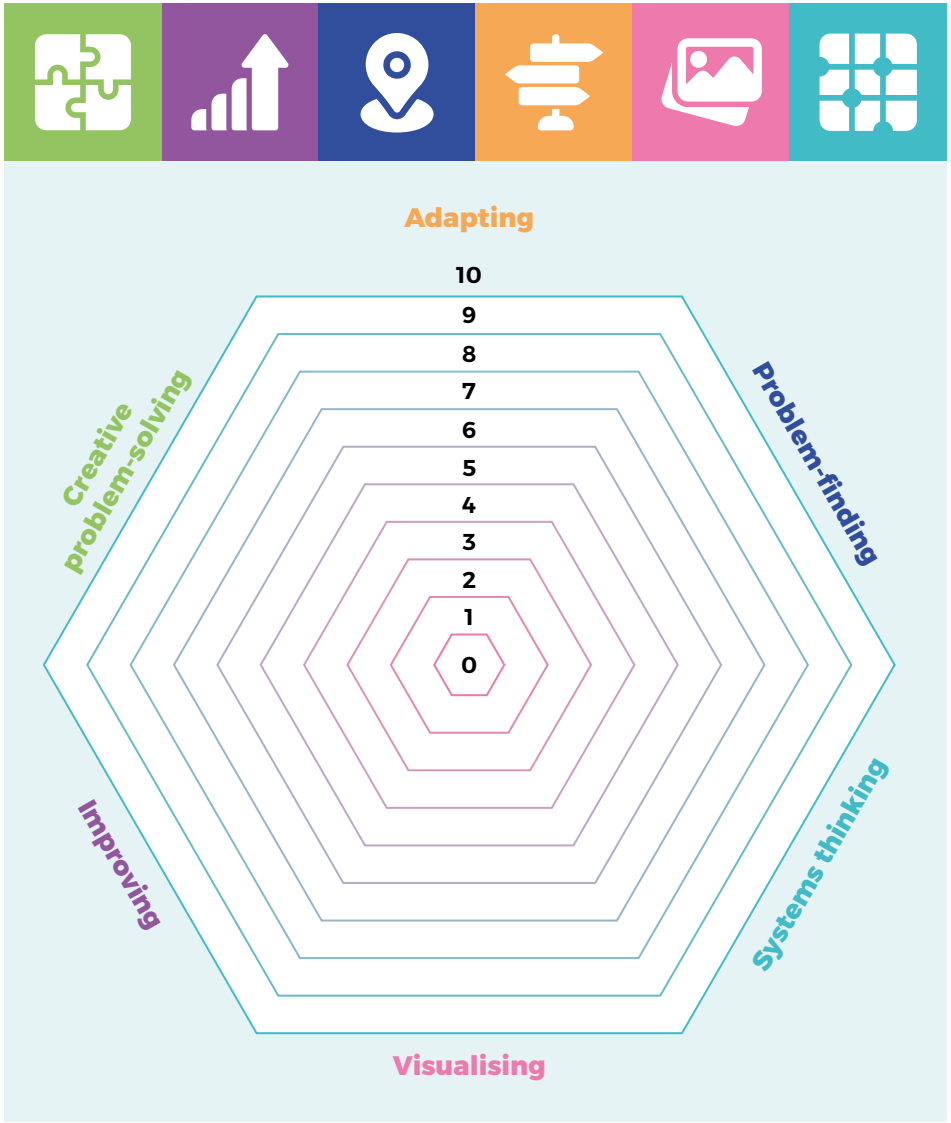
Once students complete the quiz, they can see their results on the EHoM spider diagram and can easily pick out their engineering strengths.

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 Engineering in a pandemic page on our resource hub.



ENGINEERING HABITS – STUDENT STATEMENTS

I am good at...

Creative problem-solving	Improving	Problem-finding	Adapting	Visualising	Systems thinking
Coming up with lots of new and good ideas	Making what I have done better	Thinking about the world around me and how it could be better	Deciding how something could be done differently	Thinking out loud when I am being imaginative	Spotting patterns and working out what comes next
Working successfully in a group	Experimenting with things just to see what happens	Finding out why something does not work	Explaining how well I am doing to my teachers or friends.	Making a plan before I start work	Using ideas from one subject in another
Taking on board other people's ideas and using them	Working hard and practising to get better, even when it's tricky	Finding mistakes in mine and other people's work	Evaluating how good something is	Practising something in my head before doing it for real	Putting things together to make something new
Making detailed mind maps	Working out what I need to do to improve	Checking and checking again until I am happy	Behaving appropriately in different settings	Explaining my ideas to other people so they understand	Spotting similarities and differences between things
Thinking first before doing something	Sticking at doing something until it's the best it can be	Asking lots of questions to make sure I understand	Sticking up for what I think when talking with other people	Making models to show my ideas	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 'Engineering in a pandemic' 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, 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.

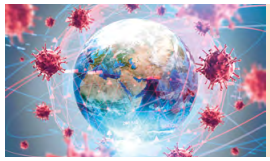
STEM BADGE TRACKER

Name:

Challenge one
Post-pandemic world

Challenge two
Model your own virus

Challenge three
Outbreak



Challenge four
Testing, testing, testing...

Challenge five
Block the way

Challenge six
Tech4pandemics

Challenge seven
Respirator challenge

SOLUTIONS AND FURTHER INVESTIGATION

Post-pandemic design challenge

To mark the vital contributions that the UK engineering community has made to fighting the COVID-19 pandemic, the Royal Academy of Engineering recognised exceptional innovations and achievements with the President's Special Awards for Pandemic Service.

Visit the full exhibition showcasing their work at the Science and Media museum.

For more ideas of design innovations during the pandemic, students can visit the **IBM COVID-19 design challenge**.

Model your own virus

Using the information provided about viruses, students can create a presentation/poster/booklet/video that can be used to show others what a virus looks like and how it behaves.

Students could choose more than the one virus and compare their characteristics. They could also research antibodies and add this to their presentation.

We have provided students with moulding (Fixit) sticks to shape and model their own virus.

Dunk the sticks in kettle-boiled water for one minute (60°C+), pinch off what they need and get moulding!

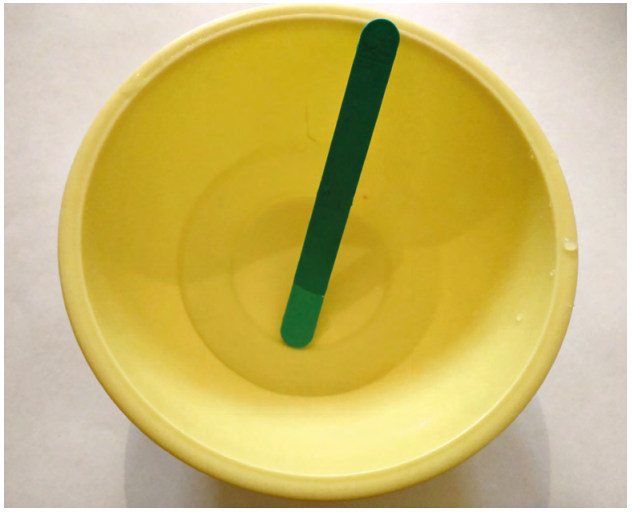
FixIts harden as they cool so they need to be kept hot whilst moulding. If students have access to a hairdryer or hot air gun (secondary schools only) are good for keeping the mould hot, or to reheat a small amount to reshape.

The best thing is that the sticks are endlessly reusable, so you can encourage students to have a go at making different models or reuse them with a new group.

Risk assessment: Students will be working with hot water for this challenge, so will need to be carefully supervised. Pre-activity discussion around working with hot water is advisable. We suggest that you use a bowl with a small amount of water so the FixIt sticks are easier to pick out.

For younger students, it is advisable for you as the teacher, parent, carer, activity leader to put and pick-up the moulding sticks from the hot water.

Mould of an antibody



Fixit stick in a bowl of hot water.

Classroom outbreak

This challenge has been designed for the classroom.

Although we would love to hear from you if you have adapted this to work as a home learning activity!

Simulate the spread of an epidemic with your class or group. This game is best played in a school, when you're able to work in larger groups.

In the game, the interaction that drives the spread of an epidemic is represented by the multiplication of numbers. One student will be given the number zero (an infected person), while the rest will be given either the number two or three.

As they multiply their numbers together in pairs, the repeated multiplication process will cause more and more people to have the number zero. The number zero represents the infection spreading through the population.

Do not give students this information before they start playing the game – save this for discussion after the game has finished.

Materials (on page 11)

- Record sheet A (for one student)
- Record sheets B and C for all other students

There is no need to interrupt play between rounds. Let students mingle freely for four to five minutes.

Once the time is up, ask students to notice the last product on their sheets. Most, if not all, of the students should have the number zero.

As a class record the number of new 'infections' and keep a record of the total number of students that are infected.

Ask students to show their results on a graph, guiding them towards a graph which shows the behaviour of the spread of the epidemic over the time (rounds) the game was played.

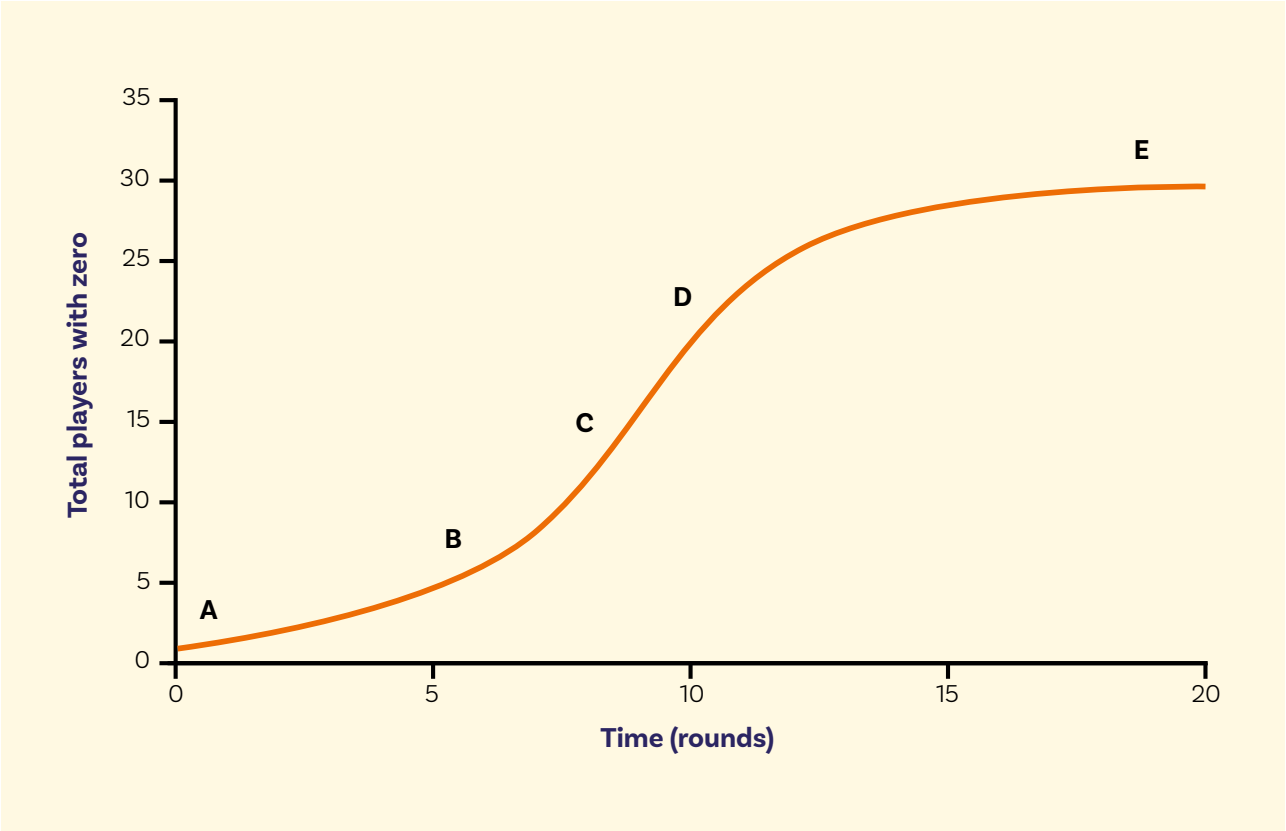
Discuss what point in the game the different stages might represent.

How does this reflect how an infection might spread across a population?

Discuss how this simulation might not be realistic. A few ideas for this are:

- The game shows an infection where there is no recovery.
- The game implies that contact with a carrier will always result in infection.
- The game does not take into account any measures to stop or slow the spread infection.

Ask students how they might adapt the game to make it more realistic.



SOLUTIONS AND FURTHER INVESTIGATION

Classroom outbreak record sheets

Record sheet A

1. Begin the round with the number shown next to 'Start' below.
2. Select another student and exchange numbers.
3. Secretly multiply the two numbers and write the product on the next line.
4. This is your new number.

Round	Number
Start	0
1	-
2	-
3	-
4	-
5	-
6	-
7	-
8	-
9	-
10	-

Teacher note: To be given to just one pupil

Record sheet B

1. Begin the round with the number shown next to 'Start' below.
2. Select another student and exchange numbers.
3. Secretly multiply the two numbers and write the product on the next line.
4. This is your new number.

Round	Number
Start	2
1	-
2	-
3	-
4	-
5	-
6	-
7	-
8	-
9	-
10	-

Record sheet C

1. Begin the round with the number shown next to 'Start' below.
2. Select another student and exchange numbers.
3. Secretly multiply the two numbers and write the product on the next line.
4. This is your new number.

Round	Number
Start	3
1	-
2	-
3	-
4	-
5	-
6	-
7	-
8	-
9	-
10	-

SOLUTIONS AND FURTHER INVESTIGATION

Village outbreak

Using the diagram or table, students can show how an infection can spread through a population of 300 people. Encourage students to spot patterns in the total number of infected people each week and in the number of new weekly infections.

Week	0	1	2	3	4	5	6	7	8	9	10
🚫 **Infected**	1	2	4	8	16	32	64	128	256	300	300
◯ **Healthy**	299	298	296	292	284	268	236	172	44	0	0

This is just one solution that they might come up with. They might use the diagram to show the infection spreading in other ways.

How quickly will this infection spread to the global population? *Somewhere between the 32nd and 33rd week of the outbreak.*

Investigate what happens if each person now infects three new people. How does this affect how quickly the infection spreads?

Week	A				**Week**
Week	A	B	C	D	**Week**
Week	AEFG	BHIJ	CKLM	DNOP	**Week**

This activity has been adapted from the **Mathalicous, Pandemic activity**.

Testing, testing, testing

Encourage students to start by using different primary coloured ink layered on top of each other to see how they separate.

Try the experiment with different coloured ink, or black ink and investigate what happens.

Block the way

Use the 5 x 8 grid handout on **page 13** As a template for the 'Block the way' activity.

Create a control line

Guide students to use a pencil line under one of the ink colours.

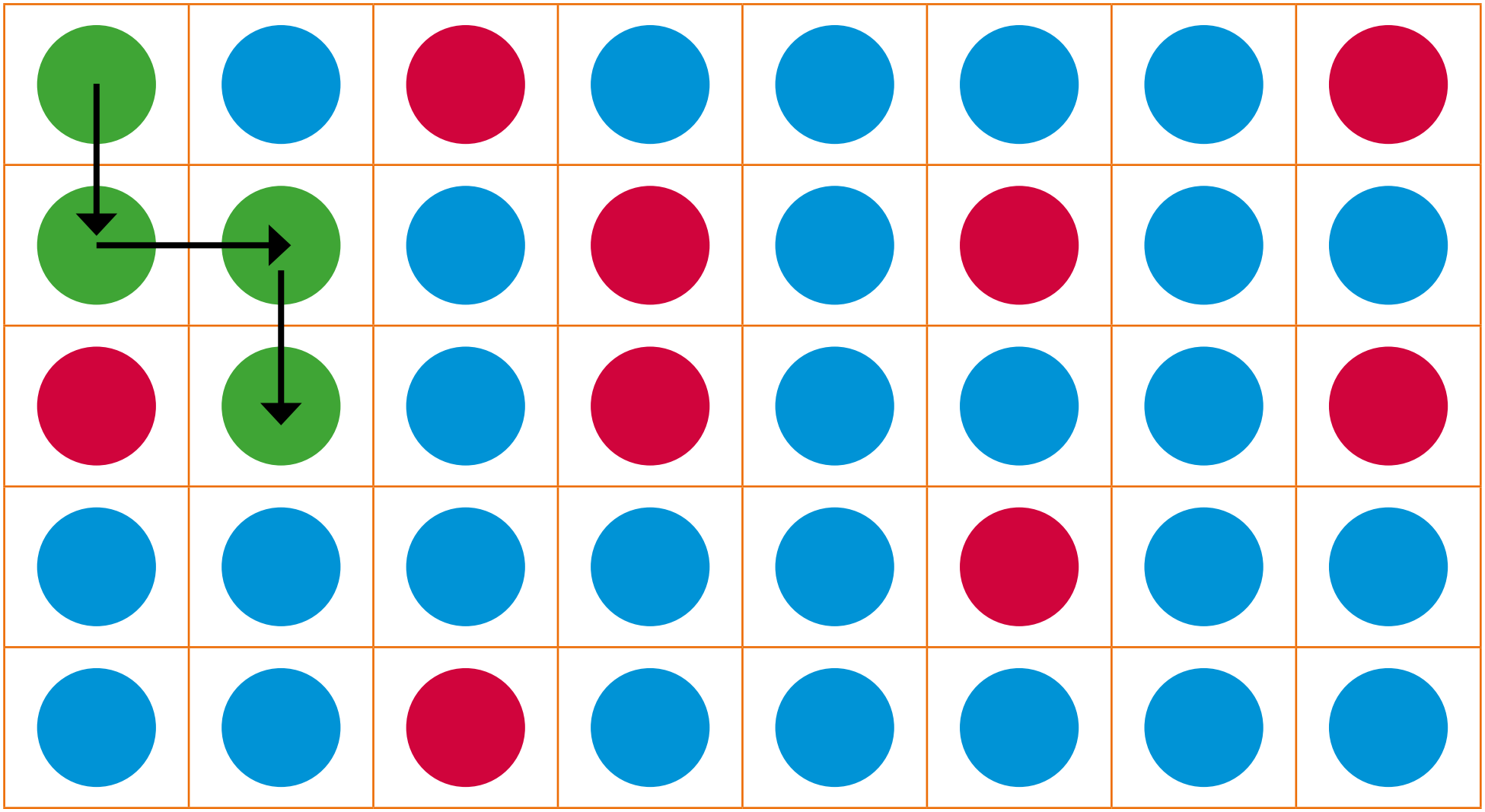
Pencils are made of graphite or lead, which will not have any interaction with the solvent (water).

BLOCK THE WAY GRID

Use three different coloured counters to represent:

- Virus carrier
- Healthy people
- People who have received a vaccine

Below is an example of how students might start playing the block the way game.



Tech for pandemics/Weird and wonderful face masks

Encourage learners to think about how the tech we use might have changed because of the pandemic.

How do they think it will evolve in the future?

The 'Weird and wonderful face masks' challenge in this resource will be followed with an accompanying **TechTuesdays free online lesson**. You can find the lesson, along with other great STEM material at **techwecan.org**

Respirator challenge

The first part of this challenge is to design and make a device to test different materials to find out whether they let air flow through and if they think they would work as an air filter for a face mask.

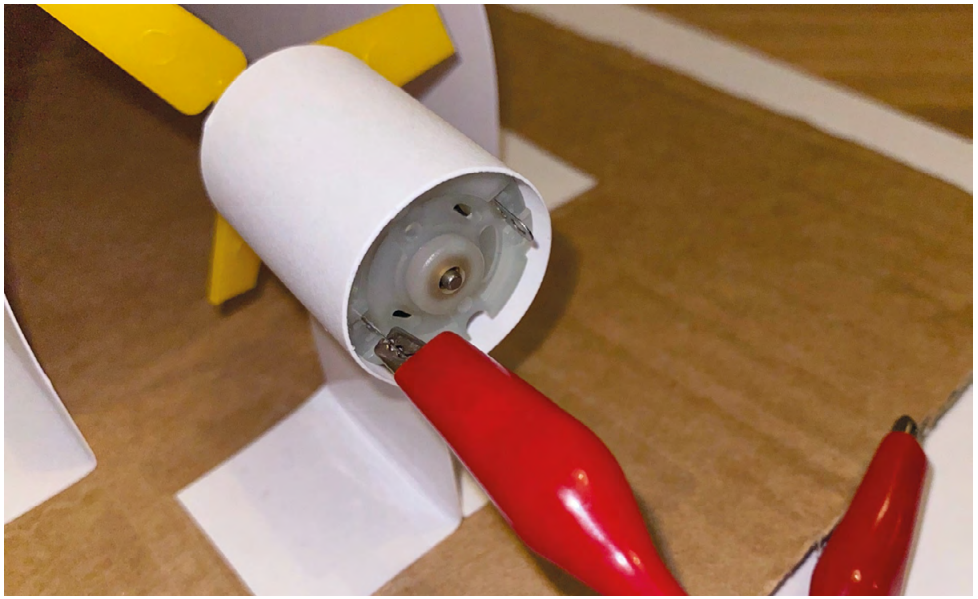
The fan will need to be twisted into shape so that it generates air flow and in the correct direction.

We have provided one example as to how they might build their testing device, but of course, we want to encourage students to come up with their own ideas and make their own adaptions.

Further investigation

Students could look into how much airflow is traveling through the different materials they are testing.

Students could look into whether the material blocks particles (such as black pepper) traveling through the material.



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