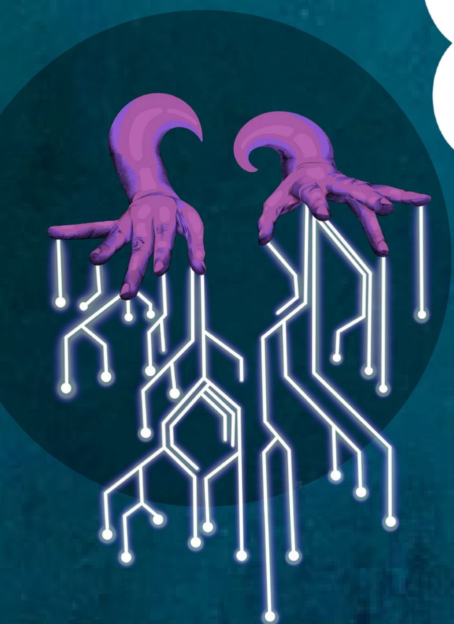
STEAM ART COLLABORATION
THE FUSION OF RESEARCH AND ART



STEAM School Resources

DPSM Resources created in collaboration with

Artists: Shevaun Doherty | David Beattie | 1iing Heaney | Peter Nash | Ed Devane
and
SFI Research Centres: APC Microbiome | FutureNeuro | iCRAG | Lero | CONNECT

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ABOUT THE DISCOVER PRIMARY SCIENCE AND MATHS PROGRAMME

The Discover Primary Science and Maths Programme (DPSM) is part of Science Foundation Ireland's Education and Public Engagement Programme, which aims to increase interest in science, technology, engineering and mathematics (STEM) among students, teachers and members of the public.

DPSM originated in 2003 with the goal of introducing primary school students to STEM in a practical, hands-on, enjoyable and interactive way. Since 2010 the programme has been run in conjunction with the European Space Education Resource Office (ESERO) Ireland.

The DPSM programme includes free STEM resources, free STEM CPD for Teachers and the DPSM Awards programme which recognises STEM work carried out in schools across Ireland.

Check out www.primaryscience.ie or email the team at primaryscience@sfi.ie for more info.

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INTRODUCTION

The STEAM Art Collaboration is a Science Foundation Ireland (SFI) Discover Primary Science and Maths initiative which aims to inspire and engage primary learners and their wider communities. It is a true collaboration between science and art and explores different STEM topics through five unique artworks.

In 2020, Science Foundation Ireland (SFI) commissioned five artworks and each artist worked with a different SFI Research Centre, to create artworks inspired by different topics in STEM. The purpose behind this project is to captivate and inspire the audience to learn more about both science and art.

STEAM SCHOOL RESOURCES

As part of the project, five unique STEAM (science, technology, engineering, art and maths) school resources have been developed in collaboration between the DPSM programme, SFI Research Centres and Artists.

This booklet will introduce teachers and learners to cutting edge research in a way that integrates the STEAM Art Collaboration with the SESE curriculum and the Visual Arts Curriculum. The aim is to inspire learners to explore the linkages between art and STEM and to experiment with how they work hand-in-hand. These STEAM resources are designed to be used alongside the artworks.

The five resources included are:

- APC Microbiome X Shevaun Doherty – *The Invisible Made Visible: Exploring PCR Testing*
- FutureNeuro X David Beattie – *Shifting Patterns of Light: Uncovering How Our Brains Work*
- iCRAG X 1iing Heaney – *Caibleadh: Discovering Our Oceans*
- Lero X Peter Nash – *Machine's Eye View: How do self-driving cars make decisions?*
- CONNECT Centre X Ed Devane – *Rotation Relay: How communications work using Space*

WEBSITE

The accompanying STEAM Art Collaboration website with the accompanying artworks is at:
www.sfi.ie/engagement/art-collaboration

CONTACT THE TEAM

For more information, please get in touch with the DPSM team at **primaryscience@sfi.ie**

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DPSM/ESERO FRAMEWORK FOR INQUIRY

The DPSM/ESERO Framework for Inquiry has been developed by DPSM facilitators & teachers working with science education specialists and is designed to be used in the planning and teaching of a topic, or theme, on the SESE Science curriculum.

The DPSM/ESERO Framework for Inquiry is designed to bring you through the inquiry based teaching and learning process as you plan and teach a particular topic or theme. **Use the following 10 steps to help you:**

CURRICULUM

1. Once you have decided on the topic or theme, write down the **Curriculum Strand, Strand Unit, Learning Objectives, and Skills Development** that you intend to address. Use the curriculum links and learning objectives in the tables in this guide to find DPSM activities that best suit your requirements. You can download the required activity from **www.primaryscience.ie**.

ENGAGE

2. Consider how you will **Engage** your learners. How will you introduce the new experience to the learners by using a **Trigger** such as a picture, video, story, “show and tell” object. This should be something that will stimulate discussion.

3. The discussion should lead to **Wondering**. This could be posing a problem, providing a scenario, asking them to brainstorm, or draw a mind map to come up with possible solutions.

4. **Exploring**, encourage learners to consider various options and to compare the alternatives that they develop.

INVESTIGATE

5. You present the problem to be investigated by posing a **Starter Question** for investigation. This could also come from the learners themselves.

6. Consider how the learners will **Predict** and provide reasons for their predictions. It is important that they record their predictions so that they can compare these to their findings.

7. When it comes to Conducting the Investigation, consider how you will organise learners to design, plan and conduct the inquiry based activity. Consider also what makes a fair test. This needs to include how they will collect and organise their data.

8. Plan for **Sharing: Interpreting the data/results**, how learners will share what they have found, what the data is telling them and how they use their results to draw conclusions.

TAKE THE NEXT STEP

9. Consider how to extend their new understanding and skills by **Applying Learning** to a new scenario or problem; **Making Connections** with the world around them or with other curriculum areas; or **Thoughtful Actions** on helping make their own environment a better place based on what they have learned.

REFLECTION

10. It is important for you to reflect back by asking yourself some key questions on what you have achieved or what could be done better the next time. If possible, provide opportunities for the learners to reflect on their own learning.

You can use the blank DPSM/ESERO Framework for Inquiry to plan out your topic or theme. The filled in DPSM/ESERO Framework for Inquiry provides some pointers for each of the steps outlined above.

DPSM/ESERO FRAMEWORK FOR INQUIRY

THEME	OVERALL THEME
CURRICULUM	**Strand:** **Strand Unit:** **Curriculum Objectives:** **Skills Development:**

ENGAGE		
THE TRIGGER	WONDERING	EXPLORING

INVESTIGATE			
STARTER QUESTION	PREDICTING	CONDUCTING THE INVESTIGATION	SHARING: INTERPRETING THE DATA/RESULTS

TAKE THE NEXT STEP		
APPLYING LEARNING	MAKING CONNECTIONS	THOUGHTFUL ACTIONS

REFLECTION

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DPSM/ESERO FRAMEWORK FOR INQUIRY

THEME	OVERALL THEME	
CURRICULUM	**Strand:** **Strand Unit:** **Curriculum Objectives:** **Skills Development:**	Use the DPSM Planning Guide to identify the strand/strand units and the appropriate curriculum/learning objectives that your learners should achieve.

ENGAGE

THE TRIGGER	WONDERING	EXPLORING
▸ Relating the new experience to the learners ▸ Using objects (e.g. torch for simple circuits, sycamore seeds for spinners etc.) ▸ Play with toys, objects (e.g. magnets) ▸ Use DVD clips, digital images of the scientific phenomenon ▸ Story ▸ The mystery box ▸ A mystery demonstration	▸ Discuss everyday experiences ▸ Concept mapping ▸ Concept cartoons ▸ Think and draw ▸ Question and answer session ▸ Free writing ▸ Brainstorming ▸ Manipulation of materials ▸ Newspaper article (fictional/actual) ▸ The science talk ball	▸ The Invitation to learn ▸ New experience presented to the learners ▸ The learners discuss this and try to provide explanation ▸ Teacher identifies learners 'alternative ideas' ▸ Learners questions about the exploration ▸ Provides them with opportunities to explore the phenomenon

INVESTIGATE

STARTER QUESTION	PREDICTING	CONDUCTING THE INVESTIGATION	SHARING: INTERPRETING THE DATA/RESULTS
▸ Starter question for investigation ▸ Teacher or learners pose the question/scenario/ present the problem to be investigated	▸ Learners record predictions and provide reasons for their predictions	▸ In groups the learners design, plan and conduct inquiry ▸ Collect and organise data	▸ Learners interpret and discuss their results ▸ Present their findings: Propose explanations and solutions based on the data ▸ Drawing conclusions

TAKE THE NEXT STEP

APPLYING LEARNING	MAKING CONNECTIONS	THOUGHTFUL ACTIONS

- Discuss implications of their findings e.g. bigger spinner falls more slowly than smaller one. Therefore if I was to jump out of a plane I would choose a bigger parachute as it would fall more slowly
- Debating
- Making connections
- Apply their knowledge to a new learning situation
- Consider how to extend their new understanding and skills – further exploration, address new questions

REFLECTION

- Did I meet my learning objectives?
- Are the learners moving on with their science skills?
- Are there cross curriculum opportunities here?
- What questions worked very well?
- What questions didn't work well?
- Ask the learners would they change anything or do anything differently.

Making the Invisible Visible: Exploring PCR testing

CURRICULUM LINKS

Strand:	Living Things
Strand Unit:	Human Life; Science and the Environment
Curriculum Objectives:	Appreciate the application of science and technology in familiar contexts; Recognise the contribution of scientists to society
Skills Development:	Questioning: ask questions about events in their environment; Observing: observe and describe processes in the environment; Investigating: appreciate the importance of repeating tests
Cross-Curricular Links:	Visual Arts (Making prints)
Equipment/Materials:	Paper, poster paint, sponge, jellyfish stencil* *A pre-cut stencil is available through APC Microbiome Ireland or alternatively a jellyfish template is provided in this pack if you wish to make your own stencil
Associated Artwork:	www.sfi.ie/engagement/art-collaboration

ENGAGE

Trigger questions

1. Can you name some things that are too small to see?
2. Can you think of some tools we can use to make small things easier to see?
3. Is it easier to see one tiny object (grain of sand) or lots of tiny objects grouped together?
4. The Coronavirus is too small for us to see with our eyes. How can we tell for certain that someone has COVID-19? (Covid-testing; having/not having symptoms)
5. What do you think happens during a COVID test? (a swab is taken, it is sent away, something is done to the sample, a result is given)

FACT

DNA is what makes you unique.
It can be found in every cell in your body and contains all the information about you including your skin/eye/hair colour, your height and genetic information. DNA can be extracted from cells to find out more information about ourselves. It is smaller than the eye can see and is in the shape of a double helix.

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Background Information

The Invisible Made Visible
https://bit.ly/3ehXylQ

It is very difficult to see something that is small and present in tiny amounts. For instance, it would be very difficult to find one jellyfish when we look at a huge ocean. It's much easier to find a jellyfish bloom (group of jellyfish) because there are thousands of jellyfish grouped together.

The PCR test (Polymerase Chain Reaction test) used to detect Coronavirus SARS-Cov-2 which causes COVID-19 works in a similar way. PCR makes copies of the coronavirus' genetic material until there is enough to detect.

The first step in Covid-testing is taking a swab from the patient's nose or mouth. The swab is sent to a lab where the RNA material in the virus is extracted and turned into DNA. Chemicals called primers and DNA polymerase enzymes are added to the DNA and then everything is put in a machine called a thermocycler. You can guess by its name that a "thermocycler" heats and cools the mixture over and over again.

The mixture goes through 3 temperature stages in each cycle.

STAGE 1
The DNA is heated to a high temperature (95 degrees Celsius) for one minute. The high temperature breaks apart the two DNA strands like a zip.

STAGE 2
The temperature is lowered to 50 degrees Celsius. At this temperature, the **primers** find only the Coronavirus DNA and stick to it.

STAGE 3
The temperature is raised to 72 degrees and the **DNA polymerase enzyme** makes copies of the Coronavirus DNA. It can only make a copy of the DNA if the primer has stuck properly to it. This means that only Coronavirus DNA will be copied – so the test is excellent at finding the virus.

The thermocycler then goes back to stage 1 and the process is repeated up to 40 times.
In this way we can create millions of DNA copies – enough to be detected.
More on DNA: https://www.bbc.co.uk/bitesize/topics/zpffr82/articles/zvwbcj6

Real world applications

Apart from its use in COVID-testing, PCR is an important laboratory technique in several areas.

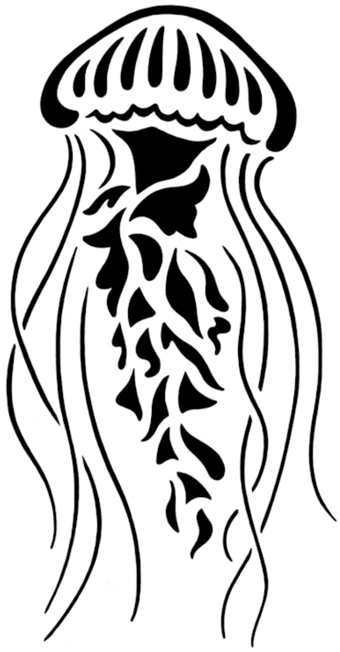
Forensics:	PCR can be used to solve crimes by amplifying small amounts of DNA collected at a crime scene.
Infection:	As well as detecting the COVID-19 virus, PCR can detect other types of infectious bacteria and viruses by adding different primers. PCR is commonly used in hospital labs.
Genetic testing:	PCR is used to amplify and detect genes associated with genetic disorders from the DNA of patients.
Agriculture:	PCR plays an integral role in detecting harmful bacteria in food, GMO-testing and genotyping plants for breeding.

PCR at APC Microbiome Ireland: Scientists at APC Microbiome Ireland, like Prof. Cormac Gahan, use PCR nearly every day to investigate if certain bacteria are present in our gastrointestinal tracts. These bacteria help us digest our food and influence our immune system to combat nasty viruses like the one that causes COVID-19. At APC Microbiome Ireland, Prof. Paul Cotter is using PCR and an approach called **DNA sequencing** to detect the types of Coronavirus strains that are currently causing problems in Ireland. Prof. Cotter runs the **Irish Coronavirus Sequencing Consortium** that can detect the older Coronavirus strain as well as new types of Coronavirus (the UK strain and the South African strain). This helps us find out how common these dangerous variants of Coronavirus are in Ireland.

DESIGN CHALLENGE

Create an 'Invisible made Visible' artwork using a jellyfish stencil.

A jellyfish template is provided if you wish to make your own stencil. Alternatively, a pre-cut stencil is available through APC Microbiome Ireland.



DESIGN

- Think about the size of one jellyfish in a large ocean, now think about a group of jellyfish together (a bloom).
- How would you like to represent your bloom of jellyfish? Why not sketch your possible designs in pencil to check that you are happy with your layout before you begin to paint.

MAKE

- Paint two sheets of paper deep blue to represent the sea and allow to dry. The first deep blue painting represents the **Invisible** (A).
- On the second sheet of paper, use the stencil to create a bloom of jellyfish which represents the **Visible** (B).
    - Put some white poster paint onto a saucer. Place the jellyfish stencil onto the blue sea.
    - Use a sponge to pick up some of the white paint. Make sure that the sponge is not overloaded with paint. It may help to have some spare paper nearby to remove some of the paint before applying to the stencil. Holding the stencil carefully with one hand to stop it moving, gently sponge the white paint onto the stencil.
    - Carefully lift off the stencil to reveal a white jellyfish.
- Repeat the printing process by repositioning the jellyfish stencil and sponging the paint onto the stencil again. Vary the position of the jellyfish. Some can even be upside down! (C).

The stencil may have to be wiped clean during the process to prevent smudging. If the white paint does smudge, simply allow it to dry. Any smudges can be tidied up at the end with some of the dark blue paint.

A. THE INVISIBLE

B. THE VISIBLE

C.

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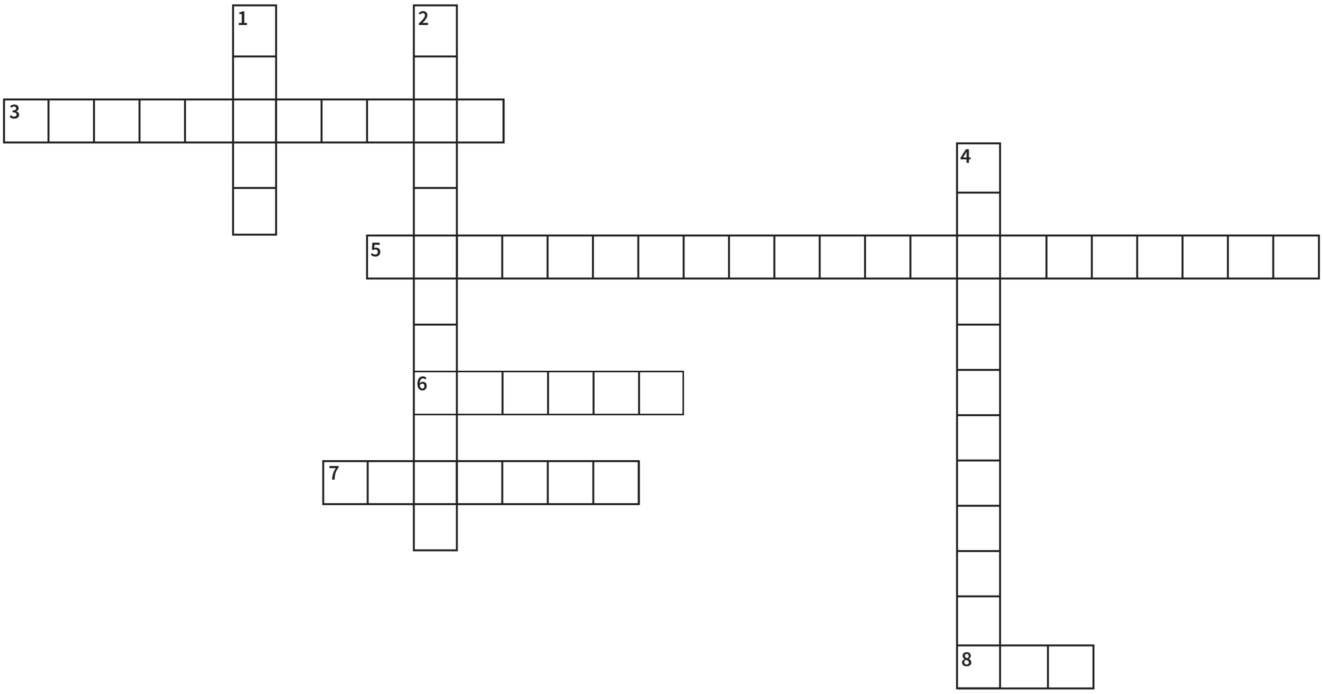
EVALUATE

- Were you happy with your design? What did you like most about it?
- What did you learn from the design process? Would you do anything differently next time?

Evaluate (senior classes): PCR Crossword



Across

3. The virus that causes COVID-19 (11)
5. The full name for DNA (16,4)
6. DNA Polymerase is a type of _______ that makes new copies of DNA (6)
7. The chemicals used to find and stick to only the target DNA (7)
8. A type of genetic material with only one strand (3)

Down

1. The process used to make many copies of DNA in the lab is called Polymerase ______ Reaction (5)
2. The shape of a DNA molecule (6, 5)
4. The machine used in the PCR process to change the sample temperature (12)

*Solutions available on last page.

TAKE THE NEXT STEP

- Learners can experiment with simpler or more complex printing techniques e.g. potato print
- To further explore STEAM, go for a walk and find some small objects (seeds, grains of sand, stones, petals/leaves), bring these back to the classroom and use magnifying glasses/microscopes to look at them up close. Now, using a sheet of A4 paper paint/draw these tiny objects as much larger images. How can artists play with size (perspective)? e.g. drawing small objects in large sizes or drawing large objects in small sizes.
- Think of your favourite thing in science and use it to inspire an artwork (music, film, drawing, painting, sculpture). Make your artwork in a style that represents you. Why not experiment using different materials to make the same thing? Do these materials work differently?
- Research different scientists that have used art to represent their work e.g. Ernst Haeckel
- Explore the structure of DNA (double helix), make your own model DNA and even experiment by extracting DNA from a banana https://askabiologist.asu.edu/activities/banana-dna

GLOSSARY/NEW WORDS

Cells: The 'building blocks' that all living things are made from. We extract DNA for testing from the nucleus of a cell.

Coronavirus: A family of related viruses including COVID-19, SARS, MERS, and some strains of the common cold. The coronavirus that causes COVID-19 is officially called SARS-CoV-2, which stands for Severe Acute Respiratory Syndrome Coronavirus 2.

COVID-19: The name of the illness caused by the coronavirus SARS-CoV-2. COVID-19 stands for "coronavirus disease 2019."

DNA (deoxyribonucleic acid): DNA carries all the genetic information of an individual and is unique to the individual (except in the case of identical twins).

DNA Polymerase: an enzyme (chemical) which creates DNA molecules by assembling nucleotides (the building blocks of DNA).

Double Helix: The description of the structure of a DNA molecule. A DNA molecule consists of two strands that wind around one another like a twisted ladder.

Genetic material: Genetic materials like DNA and RNA are sets of instructions, telling cells what to do.

Polymerase Chain Reaction (PCR): A process for making many copies of a sequence of DNA.

RNA (Ribonucleic acid): RNA molecules are similar to DNA molecules but are single-stranded.

Primers: Chemicals that help DNA polymerase know where to start assembling new nucleotides to create new DNA molecules.

Thermocycler: The machine used to raise and lower the temperature of the sample at each step of the PCR cycle.

ABOUT THE ARTIST

Shevaun Doherty is an artist who paints plants and insects. She often works with scientists (botanists and entomologists) to create very realistic images that can be used to help raise awareness about the natural world. She has been involved in the campaign to help save our bees, by painting the bumblebee image for the All-Ireland Pollinator Plan. She also paints stamps for An Post, painting the Bee Stamps in 2018, and painting the Endangered Wildlife Stamps to be launched in 2021.

ABOUT THE RESEARCHER

Prof. Cormac Gahan is a scientist in APC Microbiome Ireland.
He is a Microbiologist (someone who studies bacteria and viruses) and he investigates how our beneficial gut bacteria can protect against nasty, disease causing bacteria (pathogens) in the gut.
In his spare time, he plays and records music and likes to read.

Crossword Clues & Solutions:

The process used to make many copies of DNA in the lab is called Polymerase ______ Reaction (5). Ans: **Chain**

The virus that causes COVID-19 (11) Ans: **Coronavirus**

The full name for DNA (16,4,) Ans: **Deoxyribonucleic Acid**

A type of genetic material with only one strand (3): Ans: **RNA**

The chemicals used to find and stick to only the target DNA (7) Ans: **Primers**

The machine used in the PCR process to change the sample temperature (12) Ans: **Thermocycler**

DNA Polymerase is a type of ________that makes new copies of DNA (6). Ans: **Enzyme**

The shape of a DNA molecule (6, 5) Ans: **Double Helix**

Shifting Patterns of Light: Uncovering how our brains work

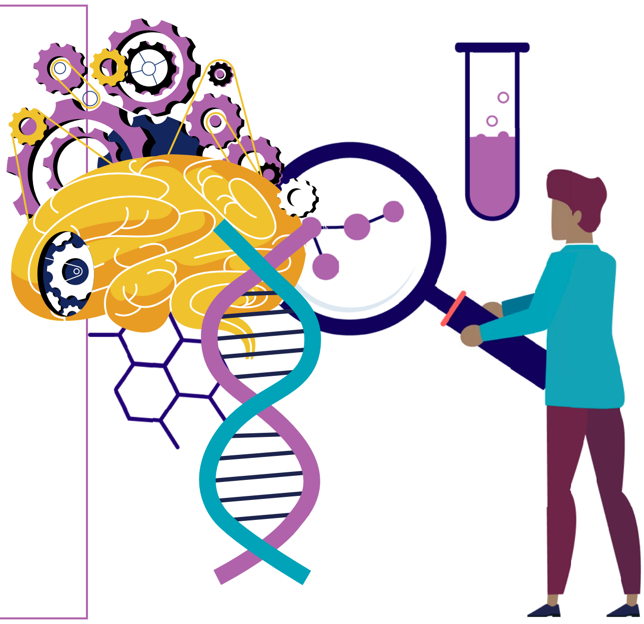
CURRICULUM LINKS

Strand:	Living Things
Strand Unit:	Living Things – Myself, Human Life
Curriculum Objectives:	Consider the use of scientific research in both a laboratory and medical setting; Appreciate the application of science and technology in familiar contexts
Skills Development:	Questioning, observing, investigating
Cross-Curricular Links:	Visual Arts, Mathematics
Equipment/Materials:	A4 or A3 paper (preferably white but can be any colour), a pair of scissors, pencil/pen/crayon, access to a tablet or computer with internet access, a printer/photocopier for the teacher to distribute copies of the tangram activity.
Associated Artwork:	https://tinyurl.com/Shifting-Patterns-of-Light
Interactive Website:	www.shiftingpatternsoflight.com
More Project Info:	www.sfi.ie/engagement/art-collaboration

ENGAGE

Trigger questions

1. What does our brain look like and what does it do?
2. How does our brain communicate with our body?
3. What happens in our brain when we perform a day-to-day task like picking up a glass of water?
4. What are neurons?
5. How neurons communicate with each other?
6. Can neuronal electricity be measured?

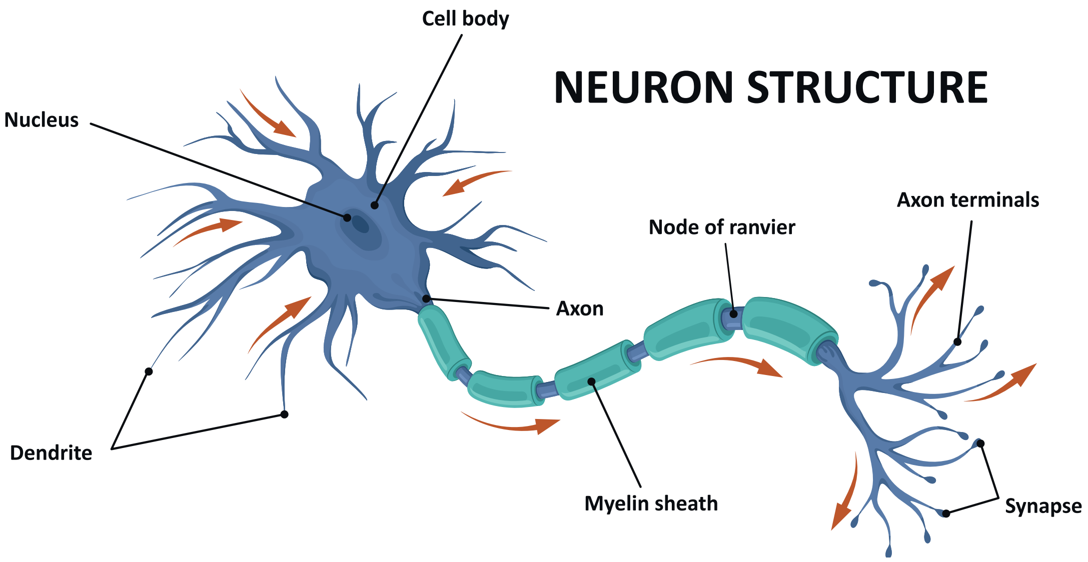


Background Information

Our brain communicates with our body by sending messages through cells called neurons. Neurons are the main cells in our brains and they communicate with each other (or send messages to our body) through fast signals (these signals can be either electrical or chemical). When we want to learn something or perform a task, our brain sends messages across a network of neurons to enable us to do this. When we do the same task many times, our brain remembers how to do that task by repeating the series of connections that help us to do something. These connections act like a bridge or pathway to getting a task done.

Learning to Cycle: When you learn how to ride a bike, you first need to learn how to balance, you might wobble a few times. Then you need to learn how to use the pedals while balancing, this is the difficult bit. Finally, you need to balance while pedalling and travelling along. You might fail and practice and then get better, eventually your body just knows what to do when it sees a bike. All this time connections are being made in your brain by neurons, these are perfected every time you practice, and the body adjusts to communicating the signals to make you move perfectly. Eventually this is a subconscious action where your body knows exactly what to do because the neurons in your brain are programmed to send the exact amount of information to the muscles that need them.

Everyone's brain has millions of connections, and it is these connections that allow us to do and think. When these neurons are activated in the brain, it is called a neuron 'firing' meaning that it is active. Multiple neurons fire at the same time to complete a task, and different neurons fire in different parts of the brain depending on the task we are doing. Neurons are present in our brains and in our spinal cord and have the ability to activate our muscles to create movement. All brains are unique and work differently – how your body and mind works compared to someone else can be completely different. It is these differences that make humans an incredible species and give us a wide range of different talents and skills. People learn in different ways, move in different ways and think in different ways all because of the individual patterns of neurons firing in our brains.



Structure of a neuron

When neurons fire, they create electricity and electrical activity in the brain can be measured using a piece of equipment called an EEG (shown in the image below), which is attached to a computer to 'read' the electrical signals from the brain. This EEG equipment can allow us to "see" brain activity. A similar type of technology can 'read' electrical signals that come from the spinal cord and travel along neurons and nerves in the arms and legs.

An EEG or electroencephalogram

Real world applications

Research on the activity of neurons can be used to:

- Understand brain growth, human development and how we learn.
- Understand different brain activity patterns and develop new treatments for patients with brains that function differently.

Neuroscience researchers help us to understand:

- How our brains work and learn.
- What causes changes in our brain activity – people's brains respond differently to different activities.
- Find out new ways to help people whose brain activity affects their lives e.g. movement after an accident, new ways of learning and new ways of doing activities to help the brain to function better.

What the researchers do

Neuroscientists study neurological (brain) differences as a team of clinicians, scientists, geneticists and researchers who work together to help patients using research and knowledge on neuronal (brain) activity.

Clinicians are doctors usually based in hospitals, and they work with nurses, pharmacists, therapists, and other medical professionals to treat patients with neurological differences. In neurology, this team help patients when the neuronal connections in their brain work in a slightly different way.

Helping the patient will involve considering all the information about the patient and their brain activity. You can think of this like solving a puzzle, at this stage the medical team will be looking at all the pieces of information like when you spread the pieces of a puzzle out on a table before joining them together.

However, sometimes we may need more knowledge about neurons, brain activity and the signals being sent between them to help patients. Some of the pieces of the puzzle are missing! To find these missing pieces, scientists and geneticists based in laboratories (often in universities) will investigate and find the missing information. They do this by doing research and experiments in their labs on neurons.
The information gained from this research over time will enable the clinician and the medical team to help the patient in a better and more informed way.

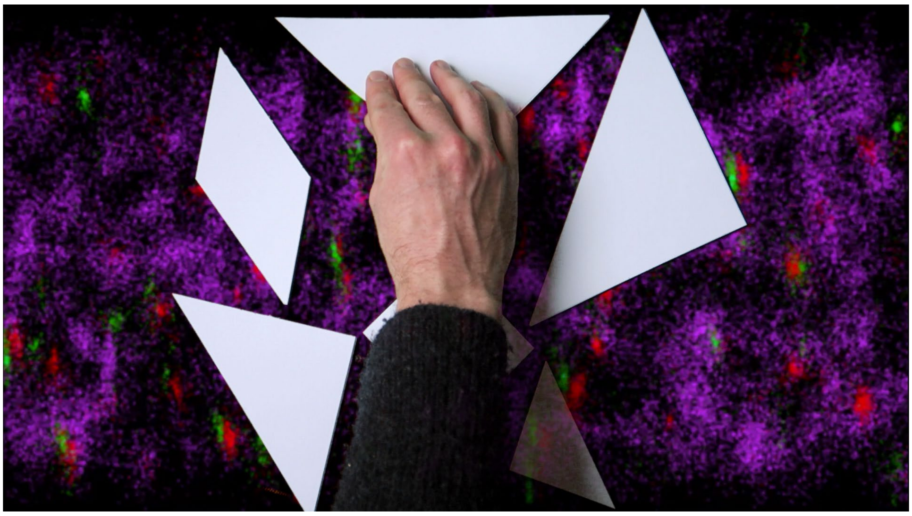
INVESTIGATIONS AND DESIGN CHALLENGES

INVESTIGATE

Test your Brain and Memory!

Find the attached sheet with triangles at the bottom of this document. Print it out in colour or black and white. If in school, photocopy this for the class. If the learners are at home, print it out for use at home.

- Cut out the triangles from this sheet of paper.
- Turn them over and reassemble to make a square.
- When you have completed a square, flip them over again and repeat the process. You can continue to do this as many times as you would like. Perhaps colour in one side orange or blue for example or time yourself to see if you can complete the square faster each time.
- As you are carrying out this activity, your brain is learning and as you start to get more familiar with the shapes and turning a bundle of triangles into a square, your brain activity adjusts to get faster and faster.



Another way to test your brain is to try out memorising some words – work in pods to memorise a list of words. If you close your eyes and associate them with a walk through your house, it makes things easier to remember. First try to think of these words in a list, read them, cover them and try to say them out loud in order.
Dinosaur, spoon, potato, leaf, octopus

Then retry, look at the words while pretending to walk through your house in your head e.g. there is a dinosaur at the front door, you walk into the kitchen and you see a spoon stuck onto a potato, you walk up the stairs to your bedroom and trip over a leaf and then you reach your room only to find and octopus lying on your bed. Keep trying this with longer lists of words and see how far you get.

ACTIVITY 2 – FINDING PATTERNS

EXPLORE

Have a look at the image, called Interferometer by David Beattie, below. Is there something different or unusual about what you see? What patterns are seen throughout nature – think of branches, lungs, roots, veins on leaves, branching of lightening. We see these branching patterns everywhere. See what you can think of.

Trees come in all shapes and sizes but incredibly what you see above the ground is the same as what is below the ground. A tree's root system grows in a similar way to the branches. They grow long and deep and spread out to find water and food, keeping the tree alive but also keeping it steady so it doesn't fall over in the wind.

PLAN AND MAKE

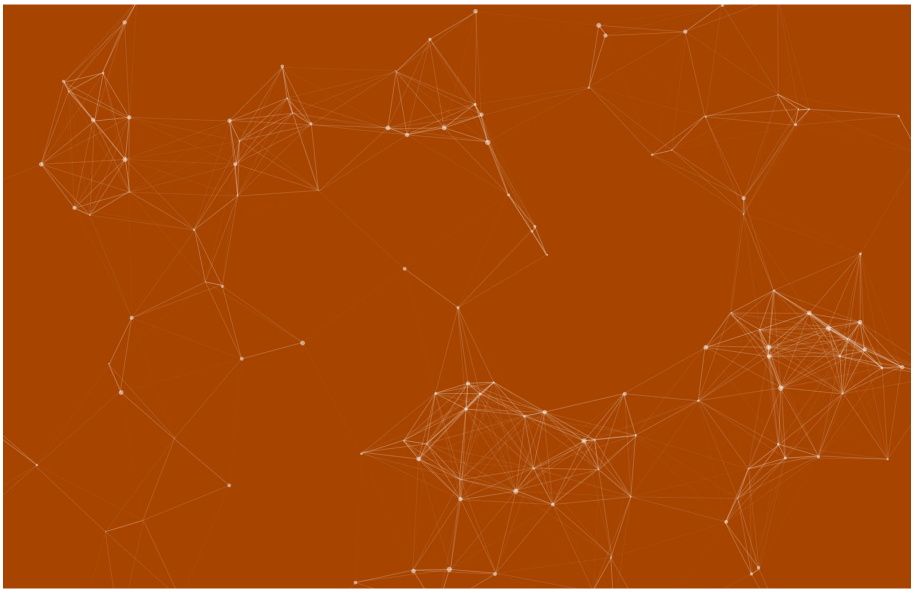
- Get a sheet of paper (A4 or A3 size) and using a pencil, or pen or crayon, draw a tree that you can see. You might find a tree outside your classroom window or go for a walk in your school yard or at home.
- Think about the branches of the tree, think about the roots that you cannot see. You can decide to include the roots of the tree in your drawing or just focus on the branches.
- When you are finished the drawing, fold your page in half and cut along this line with scissors.
- You should now have two pieces of paper with your drawing on it. Swap one of these pieces of paper with someone else in your class. If you are at home, consider doing a second drawing and mix them up. Once you have two different drawings on two different pieces of paper, turn them over and use sticky tape to stick them together.
- You can now turn over the page and you should have one drawing made from two different trees or drawn by different people. Stick them on your wall and compare with the other people in your class.

EVALUATE

You can repeat this as many times as you want. What would you do differently? Can you find different patterns?

ACTIVITY 3 – EXPLORING CONNECTIONS

Using a computer or tablet please visit the website below:
www.shiftingpatternsoflight.com



EXPLORE – WHAT CAN YOU SEE ON THE SCREEN?

- Using your mouse or finger (if using a tablet), click anywhere on the screen. Can you notice what is happening?
- When you click the mouse button a new node is created. A node is one of the dots that make up the triangular type shapes. When a new node is created it will then draw a line to the nearest dot, becoming part of this new geometric shape. As the nodes move around the screen, they will make new connections depending on where it is at that time and where the next closest node is.
- Have some fun clicking on the screen and watch what happens to your new nodes and shapes.
- See if you can follow one particular node around the screen for 30 seconds. Watch where it goes and count how many times it can make a new connection.

There is no limit to the number of nodes you create, however, if you have lots and lots of new nodes it might slow down, and you can refresh the webpage to start again.

Connections in our brains continually change as we learn new skills, increase our knowledge and make new friends. Sometimes we forget things, when we lose some of these connections and sometimes we remember something that we haven't thought about in a while, like a song that pops into your head or when you see a person that you recognise.

TAKE THE NEXT STEP

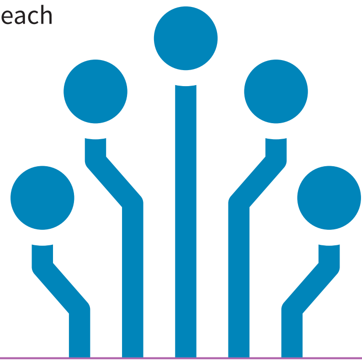
Stop by and find out more about us!

- Would you like to know more about FutureNeuro? Check us out here **https://www.futureneurocentre.ie/**
- To find out more about Epilepsy in plain English, please see our Epilepsy in English blog **https://www.epilepsyinenglish.ie/**
- Why not try some more activities? This is a super website! **https://thecraftyclassroom.com/crafts/anatomy-crafts-for-kids/brain-crafts-activities/**
- Why not find out more about what a neuroscientist does?
- **https://kids.kiddle.co/Neuron** Very helpful website on explanation of neurons

GLOSSARY

Neurons: Neurons are one type of cell in our brains and they communicate with each other and send messages to our body. These are different from other cells in our bodies like tastebuds.

Chemical/Electrical signals: Neurons communicate with each other by sending chemical and electrical signals. As well as sending electrical signals through the nervous system, the brain also uses chemical signals to control processes in the body. For example, caffeine disrupts the chemical signal that tells your brain to make you feel sleepy, which makes you feel more awake!



ABOUT THE ARTIST

David Beattie is an artist and lecturer based in Dublin. Assembled from a variety of everyday materials his work is realised through sculpture, photography and sound. He was awarded the Harpo Foundation Award (2010) and was a recipient of the Hennessy Art Fund for IMMA collection (2016). Recent commissions include The Walker Plinth (Derry, 2020), Reflectors (Bray, Co. Wicklow, 2019), and Patterns of Illumination (Griffith Barracks Multi-denominational School, Dublin, 2018). His work has been exhibited in Pittsburgh, New York, Toronto, London, Brussels, Paris, and throughout Ireland.

ABOUT THE RESEARCH TEAM

Dr. Cristina Reschke is a Pharmacist and Neuroscientist. She enjoys investigating the brain and teaching students who want to become Pharmacists in the future. Cristina's main work is to understand how the brain behaves in epilepsy and discover new treatments.

Dr. Katherine Benson – Katherine, (Katie) has a passion for genes! Not the ones you wear! A living thing's complete set of genetic instructions – or all of its genes – is called a **genome**. A genome has all of the information needed for that living thing to grow and stay alive. Exploring genomics can help understand why some people have certain conditions and some don't!

Dr. Susan Byrne – Susan works as a paediatric neurologist (a learners doctor who works in the neurology department) and as a neuroscientist. Susan loves to research to help to understand neurological conditions. Her main area of interest is in the genetic makeup of learners, why they get sick and most importantly how to make them better.

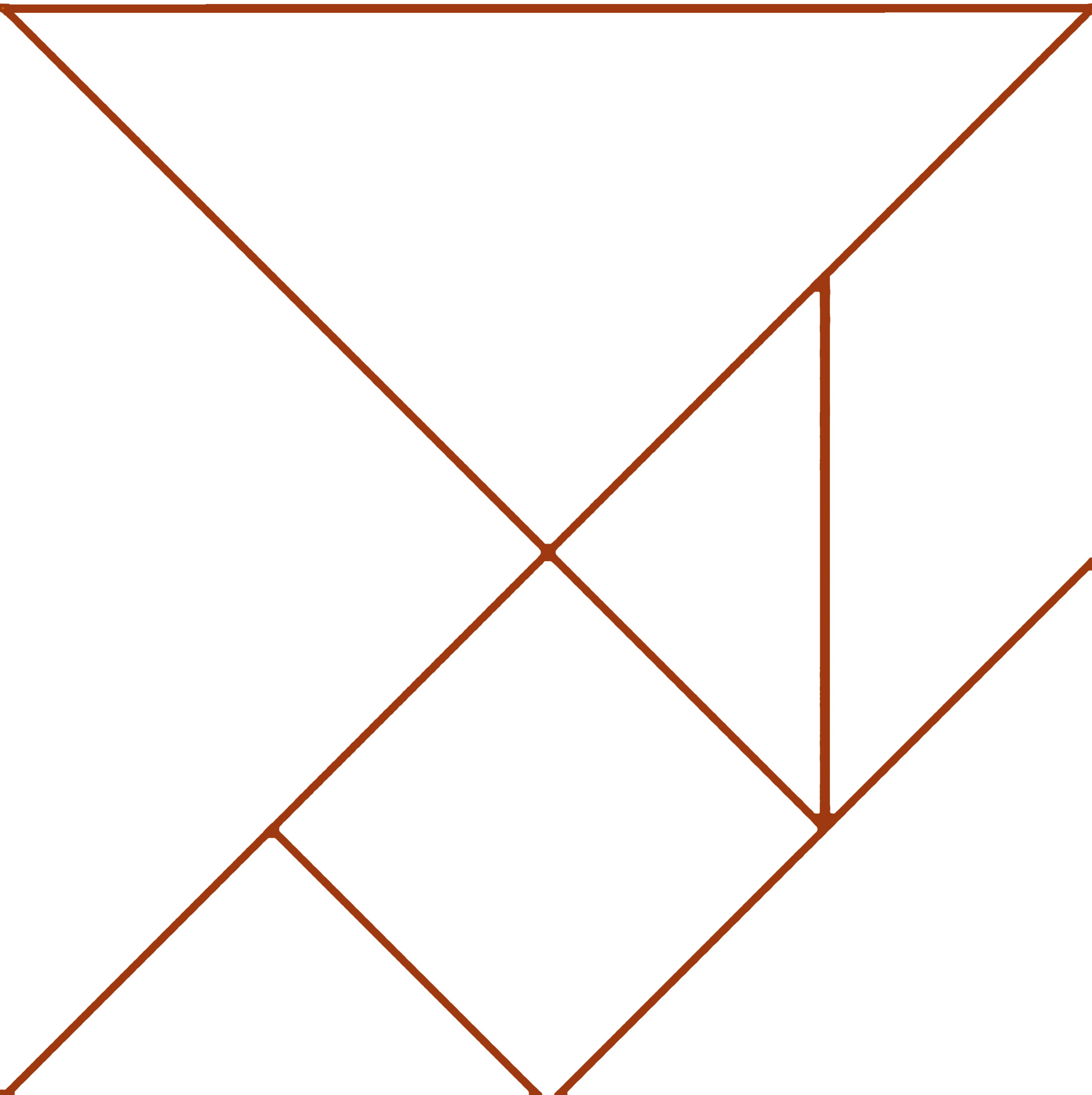
David Beattie
Shifting Patterns of Light

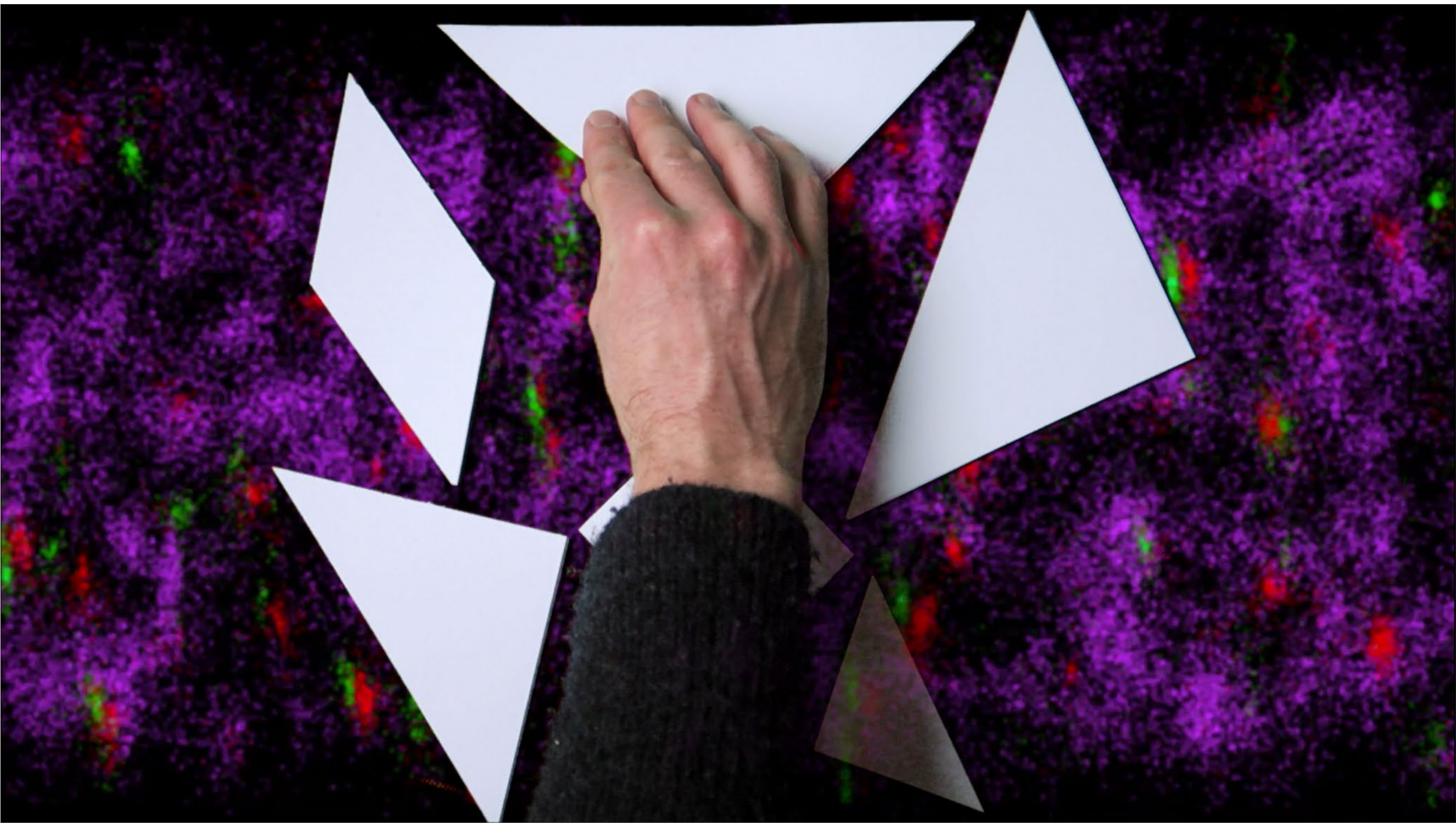
Cut out the triangles from this sheet of paper. Turn them over and reassemble to make a square. When finished flip them over again and repeat the process.

In collaboration with the RCSI research centre FutureNeuro, artist David Beattie has created new work for primary learners that will explore neural activity, finding ways to represent and think about this research through images, objects and experiences. Further information can be found on the following websites.

www.shiftingpatternsoflight.com / www.sfi.ie/engagement/art-collaboration / www.futureneurocentre.ie

Generously supported by Science Foundation Ireland

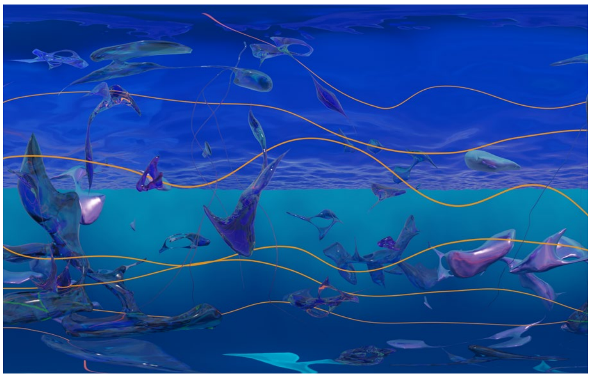




Caibleadh: Discovering Our Oceans

'Caibleadh', a VR 3D animated film made by artist 1iing Heaney, in collaboration with the iCRAG SFI Research Centre for Applied Geosciences, explores the otherworldly environment of the ocean. Using engaging colours, textures, objects, and sound, the viewer is positioned in the place of a scientific instrument. We follow its descent into the sea to explore an unknown and alien world.

Caibleadh is an old Irish word meaning "spirit voices heard in the distance at sea on calm nights" and was brought back into fashion by poet and Irish language custodian Manchán Magan who **gave the endangered word** to Prince William and Kate to act as custodians.



Underwater scene from "Caibleadh" by 1iing Heaney

CURRICULUM LINKS

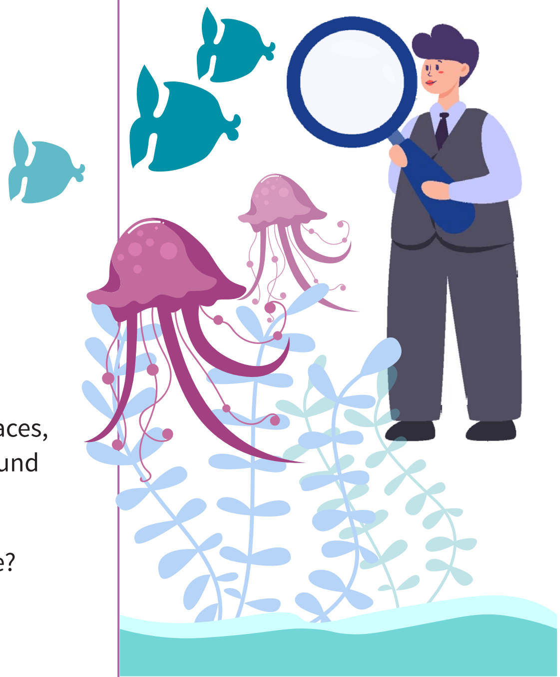
The suggested educational response activity below targets the following strands of the 3rd – 6th class science curriculum:

Strand:	Energy and Forces, Living Things, Environmental Awareness and Care, Visual Arts ▸ **Energy and Forces:** exploring how we use sounds as a form of energy to explore the sea, the sea bed, the water column and monitor marine life. ▸ **Living Things:** developing the child's knowledge of sea life including marine mammals and cetaceans. ▸ **Environmental awareness and care:** exploring the interrelationship between marine mammals and human life, and the process of scientists are currently investigating the sea and seabed offshore Ireland. ▸ **Visual Arts:** to help the learner develop sensitivity to the visual, spatial and tactile world, and to provide for aesthetic experience; to enable the child to have enjoyable and purposeful experiences of different art media and to have opportunities to explore, experiment, imagine, design, invent and communicate with different art materials.
Skills Development:	Observing, Questioning, Investigating and Designing & Making.
New Words/Vocabulary:	Hydrophone, acoustics, cetacean, seismometer
Focail Nua:	Caibleadh (otherworldly voices heard in the distance on the sea at night)
Cross-Curricular Links:	Visual arts, Geography (regions of our oceans and geology), English (new words), Irish (new words)
Equipment/Materials:	String/twine/rope, cardboard, scissors, glue, cleaned materials from the classroom recycling bin
Watch Associated Artwork (Caibleadh):	https://tinyurl.com/Caibleadh

ENGAGE

Trigger questions

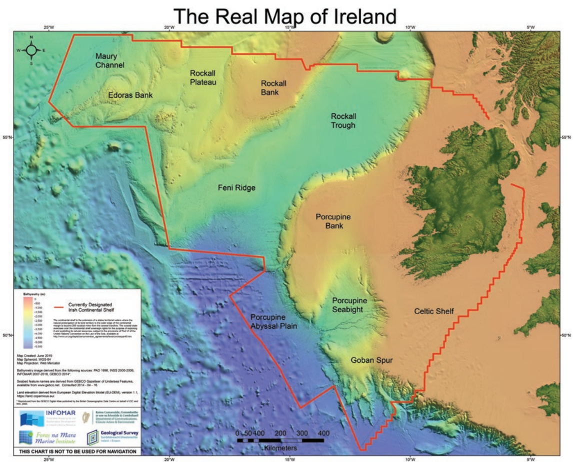
1. Play video – Caibleadh by 1iing Heaney
2. What did you see and hear in the Caibleadh artistic piece?
3. What do you think about when you think about the seabed?
4. Do you think the sea and sea bed are quiet places, or noisy places, or both depending on what is happening? How can we use sound to learn more about our ocean?
5. How do marine mammals use sound to live and communicate?
6. How can scientists use sound to investigate the ocean?
7. What do you think about when you think of a marine scientist or marine biologist?



Background Information

When you think of Ireland you may think of our beautiful island. However, the real map of Ireland (right) shows that most of Ireland's territory is actually at sea – when we include this area, it makes Ireland 10 times larger than what we can see from above the water.

Marine scientists at iCRAG carry out research on the resources needed for a sustainable future, and how we can manage our environment to best ensure environmental protection. Our relationship with the sea is key to our sustainable future: how we can harness renewable energy from marine areas, how can we learn more about our oceans and ensure that humans interact with the sea in a sustainable way.



The Real Map of Ireland was developed by the Marine Institute and Geological Survey Ireland.
Source: INFOMAR, Government of Ireland

Renewable energy

Key to this research is how we use sound to monitor the sea and build up a picture of the seabed – a part of the planet which is out of sight and out of mind for many people due to its depth and darkness. As part of this, the Irish government plans to attain 5GW of offshore wind energy by 2030 – enough to power 3.75 million homes. Where we put offshore windfarms depends on different factors: water depth, wind speed, proximity to the coast and the characteristics of the seabed where the windfarm foundations will be built. iCRAG researchers use numerous methods to build up an image of the seabed. This includes monitoring seismic waves which are waves of energy that travel through the Earth's layers as a result of earthquakes, landslides, large sea waves or man-made explosions. As these waves travel through the seabed they reflect and bounce differently, depending on the types of rocks and sand on the sea bed. Maps can be created from these reflected sounds and give us an accurate picture of the seabed

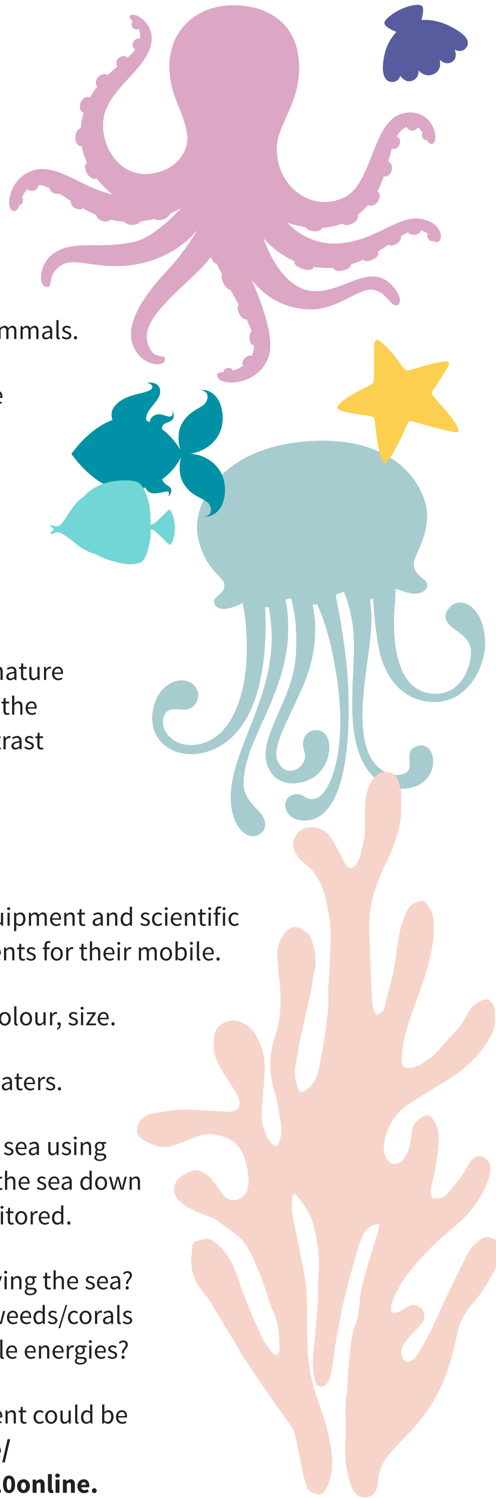
By travelling out on research vessels such as the Marine Institute's Celtic Explorer – see drone footage of a research cruise here – with specialist equipment and recording these wave patterns, we can build up a very accurate picture of what lies within the seabed and the geomorphology of the sea bed: canyons, mounds, plains. We also use ocean bottom seismometers: these are wave-detecting devices that "listen" for waves as they move through the **earths** crust, in a similar way to a doctor uses a stethoscope to listen to your heart and lungs and check your health, ocean bottom seismometers are used to build up a picture of the earth and what is happening in the seabed.

Celtic Voyager by David Brannigan Oceansport photography

Marine environment and marine mammals

Marine scientists also use sound waves to monitor the marine environment for anthropogenic (man-made) noise from ships and trawling vessels. Ireland's waters are home to many species of cetaceans (marine mammals) such as dolphins and whales, animals which are very sensitive to noise pollution. Using hydrophones – a microphone for use underwater – to record low frequency noise, we can build up a picture of how noise moves through the seabed. There are many submarine canyons off the west coast of Ireland, and our researchers have discovered that loud noises from bottom trawling vessels (fishing boats) can propagate through these canyons and into important breeding ground and feeding grounds for cetaceans. This can disturb how the marine mammals communicate – think of it like being at a party: the louder the background music, the louder everyone must talk, and the harder it is to hear and communicate. Maps can also be used to create Marine Protected Areas (MPAs) where these areas are protected from fishing or development to protect the important species that live within them. The world needs to work together to protect our oceans as many of the large marine mammals make huge migrations across the world's oceans.

DESIGN CHALLENGE



Learning Objectives: Through this activity, the learner should be enabled to:

- Learn that sound and light are forms of energy: Light travels in straight lines, sound travels in waves
- Research, identify and examine the animals that live in the sea offshore Ireland.
- Become familiar with the characteristics of living things e.g. fish and marine mammals.
- Recognise and investigate human activities that may have a positive or negative effect on the marine environment e.g. fishing, scientific monitoring, marine pollution (litter, noise)
- Explore the use of different materials and how they can be used to represent different animals, seaweeds, corals and scientific instruments.

EXPLORE

This activity centres around the creation of a hanging mobile to explore the spatial nature of the 360 experience that the student has undergone while viewing the artwork i.e. the journey from the surface of the sea to the seabed. This tactile approach offers a contrast to the audio-visual art piece that the student has experience and can also utilise the 3D space of the classroom e.g. pretend you are under the sea.

PLAN

Learners can use cardboard/paper/recycled objects to construct boats, animals, equipment and scientific instruments featured in the video or heard in the audioscape to create simple elements for their mobile.

- Investigate the different animals found in Irish waters and discuss their shape, colour, size.
- Think about the type of ships, boats, research vessels that travel through Irish waters.
- Think about how you can represent the animals found at different depths in the sea using a mobile. What other things might you find when you travel from the surface of the sea down towards the seabed? Brainstorm these ideas and discuss how these can be monitored.
- How are artists inspired by the sea? Can you think of any artworks/stories involving the sea? What materials can you use in your mobile to represent different creatures/seaweeds/corals or scientific equipment? How can artists work with scientists to design renewable energies?
- Think about how Irish mythological creatures creatively envisioned by the student could be included and read some Irish folklore inspired by the sea: **https://oar.marine.ie/bitstream/handle/10793/1396/OUR%20OCEAN%20MARINE%20LEGENDS%20online.pdf?sequence=1&isAllowed=y**

MAKE

Creating the mobile

Now that you have thought about your plans, your designs can be assembled and hung in the form of a traditional mobile. Use a boat at the top to symbolise the research cruise vessel of the iCRAG researchers and hang each of your creations at different lengths underneath the boat.

For example, the boat could be hung with string near the ceiling, hydrophones dangling from the ship, fish hung further down, coral reefs/crab/seismometers along the skirting boards. Pupils could also draw or paint an image of the sea bed on A4 paper or carboard that could be placed beneath the mobile. The use of the mobile relates to the vertical deployment of research instruments, to discover what is at the end of the line, and how research scientists can build up a 3D picture of the sea and sea bed from the safety of their research vessel on the surface of the water. The theme of marine pollution can also be picked up on by using recycled materials recovered from the recycling bin in the classroom. Some helpful steps in homemade mobile creation are outlined here.

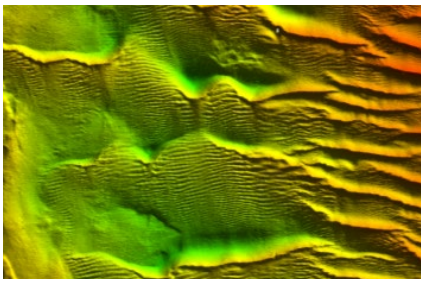
STEAM Activity

- Follow-up with a walk to a nearby seaside/lake/river or local natural area for inspiration. Take some paper and pencils with you and encourage learners to sketch what they see using their own interpretation of the surroundings. Encourage their own creative flair and style.
- Create pictures using objects found at the beach/lake/riverbanks to tell a story. Using the materials on the ground around you, create a temporary artwork in nature e.g. sand sculpture, using dead leaves to create mandalas or using twigs to make an artwork. Alternatively, when back in the classroom use rock-painting to capture your adventure.
- For very interested artistic learners, or if you would like to explore 3D animation with older classes, download Blender (blender.org) and create your very own 3D scenes.

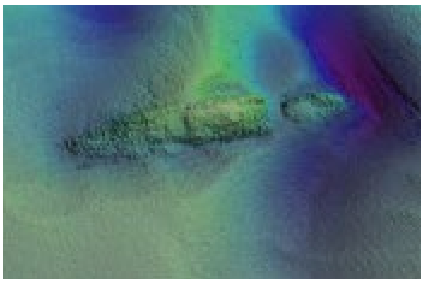
A hydrophone.

A Seismometer being deployed.
Credit SEA-SEIS.

A seismometer sinking towards the sea bed.
Credit SEA-SEIS.



A map of the sea bed showing small canyons and changes in terrain.



An image of a shipwreck off the Irish coast – the WM Barkley.
Credit: INFOMAR.

NUI Galway PhD researcher Eoghan Daly (left) with crew members on the Marine Institute's RV Celtic Voyager

EVALUATE

Once the mobiles have been made, learners should discuss what their mobiles represent and how they decided on certain materials and shapes within their work.

- Are you happy with your design? Why or why not? What would you do differently?
- Have you learned something new about the ocean? What would you like to know more about? How can artists and scientists work together to protect our marine environment?

TAKE THE NEXT STEP

- Research Irish and international artists that use the sea as inspiration for their work – how do they represent the sea using different styles? Find out more about some of the great Irish artists and writers that are influenced by the sea.
- Look up old Irish words used to describe the sea, including “Caibleadh” – Hakai magazine agus Manchán Magan’s website – **http://www.manchan.com/sea-tamagotchi**
- Discover Marine Mapping in Ireland: **https://www.infomar.ie/** including interactive storymaps: **https://www.infomar.ie/maps/story-maps**
- Identify Ireland’s marine mammals: Irish Whale and Dolphin Group – **https://iwdg.ie/**
- Take part in beach clean-ups: Clean Coasts – **https://cleancoasts.org/**
- Research Ireland’s offshore wind: Wind Energy Ireland – **https://windenergyireland.com/**
- Read more about Ireland’s marine news: Coast Monkey – **https://coastmonkey.ie/** and Afloat – **https://afloat.ie/**

GLOSSARY

Acoustics: the study of sound waves as they move.

Cetacean: a marine mammal such as a whale or dolphin.

GW: a giga-watt. A unit of power. 1 GW = enough energy to power 750,00 homes.

Geomorphology: the shape of land including the seabed.

Hydrophone: a microphone for use underwater.

Model: a method that scientists use to representing a complex problem or environment in a simplified way to aid in understanding different factors at play.

Seismic waves: forms of energy that move through the earth’s crust.

Seismometer: a scientific instrument used to monitor seismic waves.

ABOUT THE ARTIST

1iing Heaney is a visual artist from Bray, Co. Wicklow. She uses CGI film and print to explore interactions between technology and geological time. She graduated from NCAD with first class honours in Fine Art Media & Visual Culture in 2015. In 2020, 1iing completed an animation Certificate in Pulse College, Dublin. Some of her many exhibitions and achievements include ZAZ10TS, a group digital installation in Times Square, New York (2020), solo exhibitions, 'Hyper-' in Pallas Projects/Studios (2019) and 'Terrestrial/Satellite' in 126-Artist Run Gallery, Galway (2018). 1iing has received support from the Arts Council through the Visual Arts Bursary (2020) and the Covid-19 Response Award (2020) towards this project alongside SFI. Website: **https://www.1iing.com/**

ABOUT THE RESEARCH TEAM

Who we are and what we do as researchers at iCRAG

Dr Mark Coughlan is a marine geologist who specialises in mapping the seabed. Mark is like an explorer, mapping territory to figure out where the underwater valleys, sandbanks and other seabed features are in order to help engineers and wind energy companies to pinpoint where it is best to build windfarms.

Andy Trafford is a marine engineer, who specialises in building up a picture of the seabed using cutting edge technology of fibre optic cables – these are long, thin cables through which light travels and are placed in an array on the seabed. As acoustic waves move across the seabed the waves interact with the cables, disturbing the light. These disturbances can then be interpreted by Andy and his team and turned into maps of the seabed.

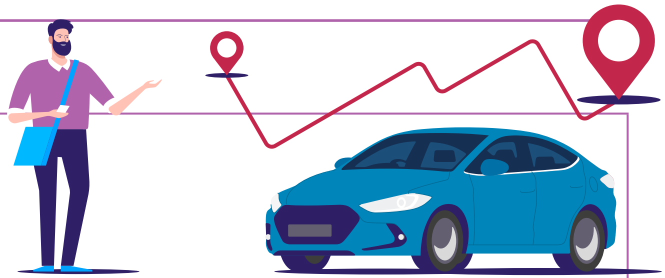
Eoghan Daly is a marine scientist carrying out research on the impact of noise on marine mammals. Eoghan is a "good listener" – he records the sounds of the sea using hydrophones, be this waves, marine mammals, or boats, and creates models to understand how sound moves through the sea and how it may impact on marine mammals.


A
B
$E=mc^2$

Machine's Eye View: How do self-driving cars make decisions?

CURRICULUM LINKS

Strand:	Energy and Forces; Environmental Awareness and Care
Strand Unit:	Forces; Science and the Environment; Caring for the environment
Curriculum Objectives:	Identify and explore how objects and materials may be moved; Appreciate the application of science and technology in familiar contexts; Identify and discuss a local, national or global environmental issue such as traffic congestion and road safety.
Skills Development:	Observing: observe and describe processes; Questioning: ask questions surrounding new technologies
Cross-Curricular Links:	Geography: Human Environments – People living and working in the local area and People living and working in a contrasting part of Ireland; SPHE: Myself – Safety and Protection: identify and explore some potential risks to health and safety in the environment; Myself and the wider world – Developing Citizenship: identify some local issues of concern and explore possible action; Visual Arts: Construction – Looking and Responding
Equipment/Materials:	▸ Paper and pencil/colouring pencils. ▸ Any materials found in your recycling bin. ▸ A toy car or something that represents a vehicle (Beebots if present in the classroom)
Associated Artwork:	https://tinyurl.com/MachinesEyeView



ENGAGE

Trigger questions

1. What is the first thing you think about when you think about a car without a driver?
2. Think about self-driving cars, would you like to try travelling in one? How would you feel if you never had to drive a car in the future? What do you think are the skills needed to drive?
3. Would a car with a human driver drive in a different way to a car with a machine driver? Why? Would there be any differences in how they see the world and how they make decisions while driving?
4. Do you think a driverless car can be "good" or "bad" based on the decisions it makes? Or right or wrong?
5. What are the advantages/disadvantages of having a human driver? What are the advantages/disadvantages of allowing a car to drive itself?

Background Information

This project examines the differences that arise when we consider a machine programmed to drive compared to a human driver. Decisions are made in a different way and these decisions can have moral consequences. Driverless cars need to put numerical values on the importance of different items that they see to make the correct decisions e.g. a human is more important than a traffic cone, so if the car comes across these two things where there is a small amount of space, it will hit the traffic cone. All of these decisions need to be programmed into the computer that operates a self-driving car and these programming decisions need to be tested numerous times to ensure that the car has the ability to make the right choice based on the seemingly infinite possibilities it might come across in the real world. People working in this area, make mathematical models of the probability of different things happening when a car is on the road. This works alongside artificial intelligence (AI) so that the car can continue to learn and update based on the situations it comes across.

For hundreds of years, humans were thought to have unique insights in the areas of morality and what is right or wrong. The challenge for future programmers is to allow cars to think ethically. It is not only a technical challenge but a philosophical one.

All this is shown in the work of Peter Nash. The artwork portrays different ways of seeing, as a machine and Peter's work addresses this phenomenon of how future cars will see the road and see all of us.

For further exploration:

- Immanuel Kant was a German philosopher that looked at ethics and how humans make decisions.
- John Berger was an artist in the 1970s who believed that art should be appreciated and enjoyed by everyone. He was a believer that art is for all and changed the language used around describing artworks.

Combining the ideas of decision making/ethics and how we view the world is combined in this project, Machine's Eye View – it is a way of figuring out how to make the "good car", a driverless car which can make decisions based on ethics and making sure it knows how to make decisions in the best way possible.

For Teachers[1]

The development of autonomous, or self-driving, vehicles offers many societal benefits and makes our lives easier. However, a number of challenges must be overcome during the design phase to make sure that we get the best from this new technology. Autonomous vehicle (AV) technology presents a new era in the relationship between society and technology. There are challenges in terms of both the complex technical aspects of making these vehicles for engineers, and how to manage the governance issues with self-driving cars which can affect governments, policy-makers and regulators who need to make sure that the cars are as safe as possible. One consistent difficulty concerns how autonomous vehicle function, in particular, how decisions made by a machine can be communicated to other stakeholders who need to make important welfare decisions regarding the use of the technology. It is of critical importance to accurately frame the functionality and limitations of socially-embedded technologies that concern human life and welfare.

[1] Based on Introduction to Cunneen, M., Mullins, M., Murphy, F., Shannon, D., Furxhi, I. and Ryan, C., 2020. Autonomous vehicles and avoiding the trolley (dilemma): vehicle perception, classification, and the challenges of framing decision ethics. Cybernetics and Systems, 51(1), pp.59-80.

As humans we can sometimes misunderstand innovative technologies because we relate their decisions to human characteristics and behaviour instead of looking at machine perception and the machine's ability to make decisions effectively. The success of AVs depends, in part, upon the transparency and explainability of the technology. In the case of AVs, the success of these vehicles depends upon non-technical people's understanding of how autonomous vehicles make some very complex decisions while driving. We need to make sure that everyone is aware of how these machines make decisions given that society and AV users are being asked to put their trust in self-driving technologies to provide them with safe and efficient transportation.

Real World Applications (Or not!)

- Autonomous vehicles are already being trialled, tested and used around the world. Why not carry out a project on these cars and look into what learners would change to make these even better. AV technology could also be applied to other modes of transport.
- AVs use a combination of technologies to work correctly, including cameras, thermal cameras (which detect heat – this is useful to tell a human or an animal apart from a wall or a traffic cone), sensors (for temperature, humidity, rain, tyre pressure, wind direction, oil levels, fuel guage, some can even detect their owner), programming and artificial intelligence. All of these technologies can be used separately for other applications. Think about what different components of a self-driving car could have other uses e.g. thermal imaging can also be used to count populations of elephants from a plane, sensors are also useful for people in wheelchairs to open doors automatically, programming already exists in some cars and is used in lots of our everyday technologies like smartphones, computers and games.
- Check out this video by Google in the Netherlands* and see what you think: https://www.youtube.com/watch?v=LSZPNwZex9s Do you think that this might be possible in the future? *April Fools joke

ACTIVITY

Images for the following activity can be found on www.sfi.ie/engagement/art-collaboration under the Machine's Eye View project page or by going to https://tinyurl.com/MachinesEyeView

How do machine's make decisions?

Using the artwork, look through a number of the images (listed below) and try to figure out all of the different things the self-driving car needs to make decisions about. Remember that we are humans and some of these decisions might be obvious to us, but because a self-driving car is a computer, it needs to have these decisions programmed to make sure it does the right thing. In self-driving cars, designers must think of every scenario the car might encounter and use coding to programme in the decisions it should make if it comes across that scenario. Think about safety for the user and other people, animals and the cars surroundings.

- Here we see our driverless car overtaking a cyclist, what does the car have to think about in order to keep the cyclist safe?

Peter Nash's Country

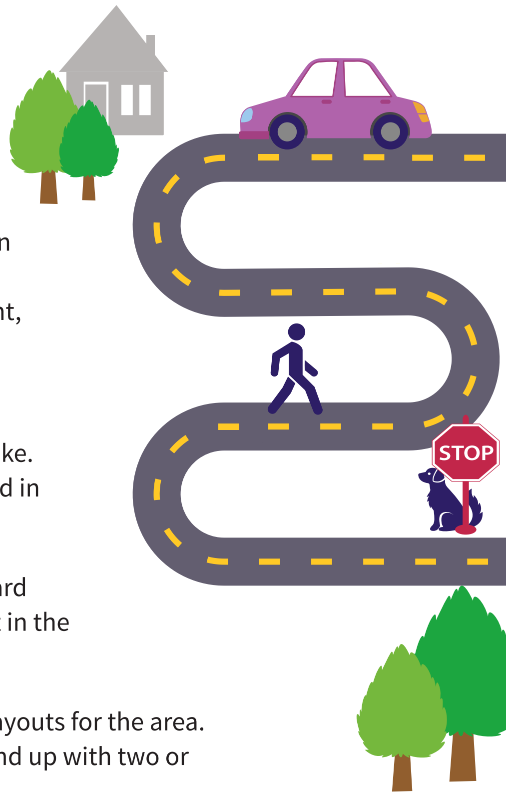
- How does a "good car" drive in the country? What does the car need to look out for? What should a self-driving car do if an animal jumps out on the road?

Peter Nash's Town

- How does a "good car" drive in the town? What are the risks? How will the decisions that the car has to make while driving in the town be different to that of the countryside?

Peter Nash's Machine's Eye View pages 10-26

- How does the car put categories on the world and how does it decide what things are more important when driving? What things in its environment help it to decide how fast to drive, when to stop etc? E.g. Stop sign, pedestrian crossing, bright sunshine, a person crossing the road, a storm.



DESIGN CHALLENGE

Build your own environment for a self-driving car

In teams and using materials from your recycling bin, learners can design and build an environment for their own self-driving car. This can be a collaborative process where everybody has a different role; designing, making different aspects of the environment, and then these all come together to form a larger group piece.

DESIGN

- To design the environment, think about what your environment is going to look like. It might be modelled on your local area, your favourite place or even a town based in the future.
- Decide where to include pedestrian crossings, road signs and other location/hazard markers. Where would you like to place your buildings? What areas are important in the place? Are there certain spots where cars can go or can't go?
- Sketched out the design using a pencil and paper. Try out a number of different layouts for the area. Use this time to try out what will work and improve on your design – you might end up with two or three drawings.
- Consider different situations that your car might come across in the environment you have designed. Think about including different characters e.g a cat, a dog, a superhero. Who or what will the car come across on its journey and what decisions will it have to make along the way?
- Once you are happy with your design, you can move to the making stage.

MAKE

- To build the environment, take the design and build the environment using recycled materials (cardboard, bottle tops, bottles), paper/card (this can be useful for the road) and paints/coloured pencils/pastels.
- Think about the size and layout of the roads to make sure that your car can fit in easily.
- For your vehicle – you could make one using recycled materials or use a toy car/vehicle.
- Now you can take your self-driving car through its environment. Have a think about how you might represent how the car is programmed to drive.
- You can make the road into boxes, like a board game and before you put your car onto the environment, write down the different instructions for where the car will go e.g. forward three places, turn left, stop at the traffic lights and continue three places once the light turns green. You can do this in pairs and take turns writing out instructions for where the car should go.
- How will it react to obstacles along the way? What happens if there is a person on the road?
- If your school has Beebots you could even programme a Beebot to move through your world.
- Consider trying out the different scenarios in the environment – how can you change your instructions quickly to make sure the car keeps its passengers and other people safe?

EVALUATE

- Did your design work out well? What materials did you use to make it?
- Is there anything you would change if you were to build the environment again?
- What did you learn about self-driving cars? How could you make these better?

TAKE THE NEXT STEP

- Learners can research the five levels of autonomous vehicles and what each different level means. Try to think of cars, airplanes, trains that already have some level of AV technology.

  Level 0 – Manual Driving.

  Level 1 – Driver Assistance.

  Level 2 – Partial Automation.

  Level 3 – Conditional Automation.

  Level 4 – High Automation.

  Level 5 – Full Automation.
- Learn more about the methods of transport and transport routes in your locality and in different parts of Ireland. Become aware of the advantages, disadvantages and roles of these different methods of transport e.g. travel time, speed, no. of passengers
- Think about impressive examples of engineering, technology and design. Use slides or printouts to look at these vehicles and design a plan or make a model which improves them or adds more features. What type of features would your favourite superhero need in their vehicle?
- Undertake a project about future technologies, moral thinking or ethical decision making, appreciate the idea of risk (how does the AV decide between one thing or another).
- Think about the role of artists in the world of technology. Artists and scientists working together can create bigger, better ideas which function well.
- Investigate how we approach problems and challenges in the world e.g. AV vehicles:
  - Investigate the causes of the issue
  - Appreciate the roles and different views of people involved
  - Identify and use ways of assessing or measuring the extent of the problem
  - Suggest possible actions and consider the effect of these on people and the environment
  - Participate in coming up with solutions to the issue, if possible

GLOSSARY/NEW WORDS

Autonomous vehicle (AV): An **autonomous vehicle** is a vehicle capable of completely sensing its environment and can operate without any human involvement. These vehicles are also known as driverless cars or self-driving cars.

Ethics: Our ethics or morals are an unwritten set of rules that tell us, as humans, what is right thing to do and what is the wrong thing to do. These can be things that we know already or things that we learn throughout our lives.

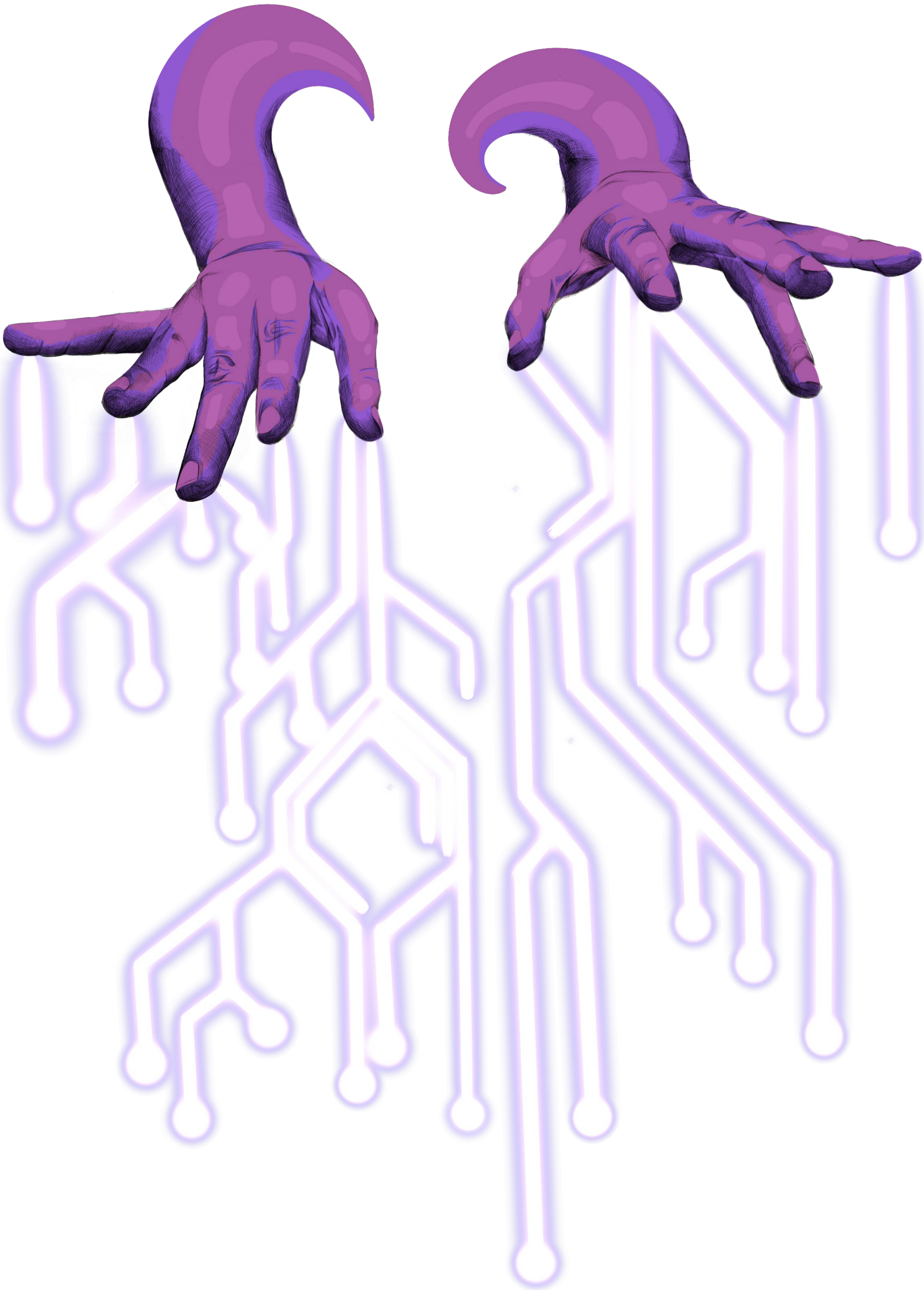
Ethical decision-making: Making decisions based on what we know is right or wrong. Humans can do this easily but computers do not have the ability to make ethical decisions unless it is programmed into their instructions.

ABOUT THE ARTIST

Peter Nash is a multi-disciplinary artist currently based in Cork City. Informed by an ongoing research into pre-internet sources of knowledge and methods of communication, his practice includes drawing, printmaking, animation, and sculpture.

ABOUT THE RESEARCHERS

Lero researchers, Professor Martin Mullins and Clare McInerney, work on the challenges facing the development of driverless vehicles, especially those working in the same environments as pedestrians, animals and human-operated vehicles across the automotive, industrial and agricultural sectors.



Rotation Relay: How quantum communications work in Space

CURRICULUM LINKS

Strand:	Energy and Forces
Strand Unit:	Light: Learn that light is a form of energy; know that light travels from a source
Skills Development:	Working Scientifically; Questioning, Observing, Measuring, Recording, Interpreting and understanding results.
Cross-Curricular Links:	Visual Arts; Maths
Materials Needed:	▸ A coin or two-sided ball/marble (any item that can be made spin at high speed with 2 distinct sides) ▸ A glass or beaker ▸ A sponge ▸ Water
Associated Artwork:	https://tinyurl.com/RotationRelay (Epilepsy warning for this video)

Note: This is a theory-based physics activity to understand the different aspects of quantum communications. It is geared towards the senior end of primary school and may also suit some post-primary schools under the topic of physics. The explanations in the background section accompany the activities which are explanatory activities within this resource, and it relates to the security of data/information as it travels from one place to another. Quantum communications is envisaged to be the future of the internet for banking and sending secure information that cannot be hacked easily.

The Artwork for Rotation Relay is an interactive musical gyroscope that represents all of the theory laid out in this resource using sound engineering, lasers, movement and has an interactive dashboard that enables the user to control the different speeds, tones and movement. This shows the importance of using art when working with STEM as it allows us to portray difficult concepts and also to come up with great ideas which scientists may not have thought about.

ENGAGE

Trigger questions

1. What is light? (A form of energy) How does light travel and how do we know this? (Light travels in straight lines and we can block light e.g. by closing a curtain, creating shadows)
2. How can we make light travel in lines that are not straight? (Using refraction e.g. if you put a pencil into water it looks like the pencil is not in one straight line; or using reflections e.g. using a mirror to bounce light coming from a torch in a different direction)
3. How do we send information from Ireland to the USA? (via fibreoptic cables) How fast can we send this information from Ireland to the USA?
4. Can you think of any way that would be faster?
5. How can we send lots of information and make sure that it is kept secret/secure?

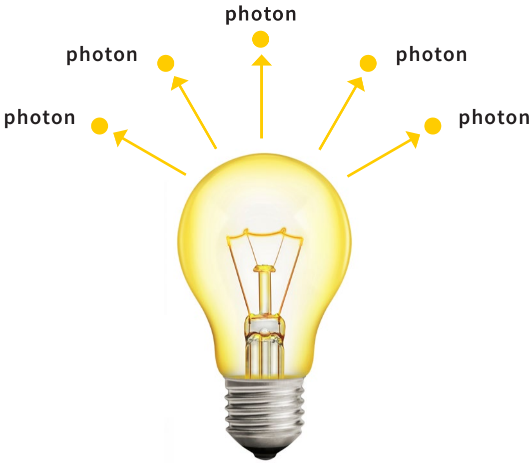
Background Information and Theory for Classroom Use

This activity introduces several complex concepts more suited to 5th and 6th class. This resource will guide you through what photons are and introduces some of the concepts around quantum communications (using photons to transport data), binary code (computer communications using 1/0, on/off) and how we can send information more securely from one place to another using quantum communications.

Firstly, did you know that light is made of small packages of energy called photons?

Photons

A photon is simple a parcel/package of light (energy really). Photons are the basis of how light bulbs work, or lasers. Light bulbs and lasers release photons as the electricity applied to the atoms that make up their filaments (light sources) become too energetic. The lightbulb releases photons to reduce the build-up of energy and this brings the atoms contained in the filament back to a stable energy state, while continuing to emit light.



In simpler terms, when we turn on a light switch, electricity moves through the filament (or light source) in the light bulb and this gives the filament energy (electrical energy -> light energy). When the energy becomes too much, the filament wants to get rid of the extra energy and so it releases photons, which emit light and allow us to see.

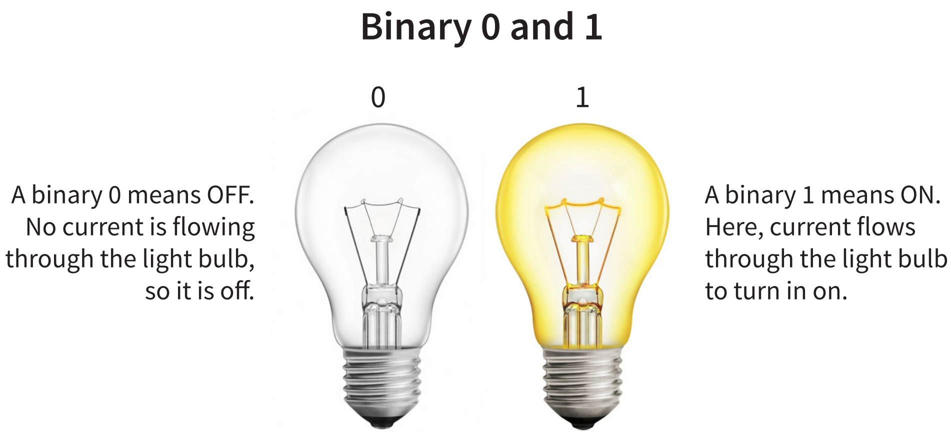
Sending data using photons

As photons are tiny parcels of energy, we can use them to our advantage to send information across the world at very high speeds.

Think of your fibre broadband. Fibre broadband uses fibreoptic cables (cables which can carry light) as thin as a strand of hair to send light flashes from one place to another which are interpreted as data on the receiving end. A computer can decode the messages being sent by these light flashes into the videos you watch online or into the text that you see when you open an email. This allows us to send messages extremely quickly!

Binary code

Another way of sending data is using computers which communicate using binary code. When you flick a switch for a lightbulb it is either on or off. We call this binary, something is either in one state or another with no in-between e.g. a coin is either heads or tails, a lightbulb is either on or off, or in computer code something is either 1 (on) or 0 (off).



Check out the button on some of your electronic devices – it usually contains a symbol which is a little 1 inside a 0 to indicate 1 (on) or 0 (off). <Image here of the power button containing 1/0 if possible>

Much like humans communicate using language or count using increasing numbers, computers use different combinations and patterns of the numbers 1 and 0 to communicate. Certain combinations of 1s and 0s mean different things and it is easy for us to translate once we understand the language – computer programmers need to understand binary code.

Quantum communications

Unlike computer code which can be easily worked out and can be hacked easily, quantum communications relys on the quantum properties of photons such as superposition (explained below) to transport information using photons.

Quantum communications are very important for the future of communications, especially data which is contained in photons that are travelling through free space (explained below) instead of fibreoptic cables. This will send photons containing data into space towards satellites which will bounce them towards their destination – this is much faster and more secure than current fibreoptic internet. At any one time there could be millions of photons bouncing around us which contain data and it is important that this data is kept secure for the sender and the receiver.

Researchers in CONNECT look at quantum communications using photons which will be better at keeping our information more secure as it travels from place to place using quantum properties.

Superposition

This is a quantum property where a photon exists in more than one state or more than one place at the same time – referred to as a superposition where the photon exists in multiple states. It is very difficult for us to imagine something being in more than one place or state at the same time, even for the scientists who work in quantum mechanics! As photons carry data around, they stay in this in-between state or superposition which is much harder to hack than binary code as it is not easy for hackers to translate.

The only way to find out the exact state of the photon is to measure it. Measuring the photon reduces all of the possible states of the superposition to one, allowing us to know for sure which state the photon is in. This is called 'collapsing the wavefunction'. So by measuring we cause the superposition to stop, the photon then loses this quantum property and we have a measurement.

To imagine superposition, think about a coin. When the coin lies flat on a table it is either has heads or tails facing upwards, i.e. it is either in the state of heads or tails. Then think about spinning the coin on it's side – while it spins it blurs into a superposition of both states and you cannot tell whether it is in the state of heads or tails. To measure the state, you will need to stop the coin and it falls to the table. Now, you have collapsed the superposition. At this point when you go to measure it, your coin will only be heads or tails. As data is carried around in photons for quantum communications, it stays in a superposition. This can only be decoded once it reaches its destination.

The measure of 'heads' or 'tails' is an example of a data point and this is directly related to *degrees of freedom*.

Degrees of Freedom

Degrees of freedom are the number of characteristics in a system that you can assign values to, or that you can measure. Our system here is the spinning coin and we can think about what degrees of freedom or characteristics we can attribute to it. Here are some examples:

- Is the coin heads or tails?
  Here we are looking at 1 degree of freedom (one characteristic) with 2 data points (two possible answers, heads or tails).

- Is the coin spinning clockwise or anti-clockwise?
  1 degree of freedom (The direction of spinning), 2 data points (Clockwise or Anti-clockwise)

- Is the coin standing upright or flat?
  1 degree of freedom (The position of the coin), 2 data points (Upright or Flat)

- Is the coin standing upright or flat? Or, at differing degrees from the table?
  1 degree of freedom (The position of the coin), 6 data points (flat (0°) or at 15°/ 30°/ 45°/ 60°/ 90° from the table)

This question measures the orientation or polarisation of the coin and depending on your question could range from 2 data points (upright or flat), up to 6 if you wanted to include a range of possible answers that measure the in-between angles e.g. flat (0°), 15°, 30°, 45°, 60°, 90°.

Decoherence

The disappearance of some of the above quantum properties (superposition) because of the interaction with the surrounding environment. Again, think of the coin spinning. It will eventually run out of momentum (due to the friction of the table and the air friction) and stop – therefore it loses its superposition.

Fibreoptic transmission

Fibre optic transmission is a way of sending information in the form of light through thin fibres. The fibres are usually a clear piece of plastic (sometimes glass) inside another. These are tiny, about the thickness of a hair! https://en.wikipedia.org/wiki/Optical_fiber

Photons of light are sent down the inner strand which then bounces against the edge of the outer strand along the length of the fibre. This happens because the inner and outer parts of the fibre refract light differently. Refraction is how light bends when it moves through different substances. Have you ever noticed that your straw looks different when you look at it through your glass of water? Think of trying to pick up a stone in the sea or from a swimming pool, refraction can make it seem like the object is in a different position to where it actually sits. https://www.khanacademy.org/science/physics/geometric-optics/reflection-refraction/v/refraction-in-water Another refraction activity: https://www.sfi.ie/site-files/primary-science/media/pdfs/col/dpsm_esero_investigating_refraction.pdf

In an optical fibre, this refraction makes the photons of light look like a wave as they pass through the fibre. Watch this video to understand how optical fibres work: https://www.youtube.com/watch?v=0MwMkBET_5I

The fibre optic cable guides photons from one place to another and try to protect them from decoherance (losing some of their quantum properties due to interaction with the environment around them), but there is a cost. Because the light is not travelling in a straight line through the fibre, it's journey is longer and this makes it slower. They travel as a wave rather than in a straight line. If you draw two points on a page and draw a straight line and a wave between them you will see that the wave is a longer distance between two points, so the photons have a longer path to travel than if they were travelling in a straight line along the fibre.

The plastic or glass that the fibre optic cables are made of lots of atoms that might also have impurities in them (particles that do not make up the plastic and shouldn't be there). The photons can bounce into these along their journey. Travelling as a wave and hitting into these impurities along the fibre can slow the photons down to about half the speed of light which is significant when they are travelling long distances (to another country). Slower photons will mean that the information they're transmitting won't get to its destination as quickly.

These atoms/impurities will also eventually start to degrade the wave (decoherence) as they will start to block parts of the wave, at distances up to 80km. To overcome this, amplifiers are used along the cable to regenerate the photonics wave by making a copy of the photons to pass on to the next section of fibreoptic cable. To do this you need to measure the photons and copy them.

Unfortunately, this causes issues when our photons have quantum properties, as once the amplifier measures them they lose their quantum properties. Think again of stopping the coin. You can restart it after it stops, but it's no longer the same spinning coin, it might look the same to you and I, but the direction that it's rotating or the way it spins will be slightly different.

Free space transmission

Free space transmission is another way to use photons to send information. In this case, they are sent through the Earth's atmosphere (the air) and out into Space.

In the lower atmosphere there are lots of atoms and molecules floating about like oxygen, nitrogen, carbon dioxide. These will interfere with the photon as it is travelling, which slows the photon down and can cause it to decohere. However, this part of the atmosphere is only 12 km thick, and scientists can use high-powered lasers to push the photons through this layer to lessen any interference (Use Google Maps to check see what lies within 12 km of your school – it is not very far). Once these photons are through the lower atmosphere and out in Space, there is nothing left to bump into and they can continue to travel at the speed of light. This allows them to retain their quantum properties like *superposition* reach their intended satellite and get transported to their destination.

Real World Applications

We all use fibre optic transmission – up to 400Gbps or 400,000Mbps.(Gbps = Giga bits per second, Mbps = Mega bits per second). In a home setting using WiFi it is usually 30Mbps, 100Mbps, 250Mbps or 1000Mbps/1Gbps. Really good for online gaming, video calls, and internet TV. However, you need to have the fibre optic infrastructure in place, which is very expensive. Think of the National broadband Plan.

Free space transmission can also be very fast and is useful for providing access to the internet in remote locations. Traditionally Geo stationary Satellites were used, but they are so far away, about 35,000km (so up and down would be 70,000km) that the latency (delay) used to be high making them no good for gaming, or video calls.

These days Low Earth Orbit satellites are starting to be used, they are relatively cheap and up to 1,000 times cheaper than when they were first produced (€250k today vs €250M in the past for a geostationary) and in-orbit they are between 500km and 1,000km above the Earth's surface, so a maximum distance (up + down) of 2,000km vs 70,000km in the older models. However, new satellites are not stationary, they move in orbit so rather than having one satellite, a 'constellation' of these satellites are required. SpaceX are doing this with StarLink which you can see in the sky as a row of lights when they are passing over Ireland (https://www.starlink.com). However, the data rates are not as good as fibre optic ~ 50 -150Mbps.

Quantum communications technologies add 2 extra features over regular communications.

1. Super-position allows for a higher density of data which means higher data rates and speeds.

2. Data being transmitted is very secure and you will know if someone tries to copy this data or measure the photon carrying the data as it will decohere before it arrives at the receiver and therefore won't make sense.

So the application that we are looking at is very fast (low latency/delay), very secure, and high throughput data transfer (which could be online gaming, video calls, or internet banking etc) between countries.

Nasa are looking to deploy a 4G network on the moon in preparation for a permanent moon base. https://www.nokia.com/about-us/news/releases/2020/10/19/nokia-selected-by-nasa-to-build-first-ever-cellular-network-on-the-moon/

This will obviously link back to earth via a free space transmission link, which Nasa will want to be secret (other countries could try and intercept the transmission to see what is going on at the moon) and so the will also use quantum technologies to secure that transmission.

What the researchers do

We look at emerging (next generation) networking protocols. An easy way to think about this is the evolution of 3G to 4G to 5G internet which is rolling out now. We are looking at the internet beyond 5G (or 5G+) and also 6G, which we expect will become mainstream around 2030.

We explore the additional features that we would like to see for 6G internet – faster speeds, higher data rates (so you can use your phone to project a holograph of a football match that you are watching, think VR but without the headsets and you can move around the pitch and share it with your friends etc), more security (so you can have a digital currency – rather than paper money) and the fact that many more devices will be connecting to the network. Your lightbulbs, even your clothes and the wallpaper in your house, might all eventually have minicomputers in them in the future and these will need to communicate with other devices. To add more reach to places which are remote, LEO satellites can be used in rural locations (even on offshore islands in the Atlantic) rather than using mobile phone masts.

INVESTIGATE

ACTIVITY 1 – UNDERSTANDING SUPERPOSITION

This activity is linked with the explanations of photons, sending data using photons, binary code, quantum communications and superposition (above).

The spinning coin as an example of a quantum communications system.

- Your coin should have two separate sides (heads/tails), these represent two states or values. If you flip the coin it should land on either heads or tails. This is how binary code in computing works – imagine heads = 1 and tails = 0. The state of the coin is represented using either 1 or 0. This is easily translated e.g. if I told someone that the value of my coin was 1, and they knew binary code, they would be able to tell that it landed on heads. Flip a coin 5 times and record which side it lands on using numbers only. All computer code is a combination of 1s and 0s that mean different things. This is easy for hackers to decode.

- Now, make your coin spin. Use your fingers to spin it on its edge so that the two sides start to blend into one image. What happens when the coin is spinning? Is it easy to see both sides separately? Is it showing the value of heads or tails, or both?

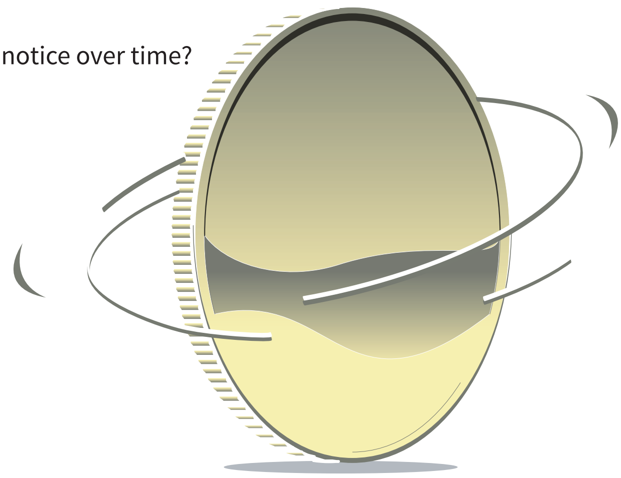
  This in-between state, the blur where you cannot see the final value is called superposition. Photons carrying data stay in superposition when they are travelling meaning that we are not sure which state (heads/tails) they represent.

- While the coin is spinning would you expect the coin to land on heads or tails (the coin has two values, it is in a superposition of heads and tails)?

- In order to measure the state of the coin, knock it over flat with your hand. What happens?

  It is now in a state or either heads or tails and we can take a measurement. Now we know exactly what the outcome is – the coin has either landed on heads or tails.

- Repeat the spin several times and note your results. What do you notice over time? (A statistical average of around 50/50 results will occur over time)



ACTIVITY 2 – EXPLORING DEGREES OF FREEDOM

Following your understanding of superposition, degrees of freedom is also explained above. An activity to work alongside this is as follows:

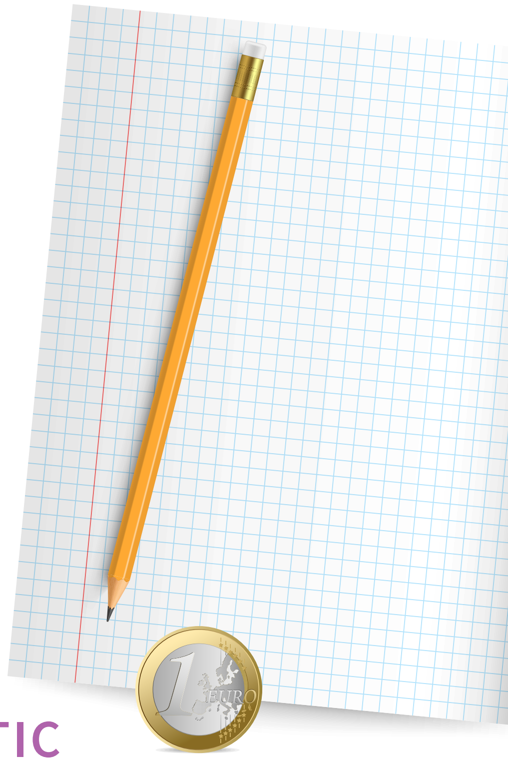
- Put a piece of graph paper on the table and write large letters on it, starting at the centre of the paper and radiating out.
- Spin the coin, look at the direction and distance travelled. Wait until the coin stops moving and note if it landed on a number or a letter.
- When the coin lands on a letter – heads represents a capital letter, if it lands on tails it represents a lower case letter.
- How many spins would it take to create a word? See if your coin spins spell out a word. Record your results e.g.:

  Spin 1 + Letter 'a' + heads = A

  Spin 2 + Letter 'n' + tails = n

  Spin 3 + Letter 't' + tails = t

  Word: Ant in three spins.



In this method one spin will give you one letter. How does this compare to other types of coding? For example, if you're communicating through Morse Code with a torch you need an average of 3-4 flashes of light to get a letter. In binary you need 8 bits (a combination of 0s and 1s) to represent one letter.

ACTVITY 3 – FREE SPACE VS FIBRE OPTIC

This accompanies the last explanations in the background section and looks at the differences between fibre optic transmission (slower, through fibreoptic cables) vs. free space (lasers sending photons containing data out through the atmosphere to satellites and directly transmitting to the receiver).

- Pour water into your beaker or glass and measure the amount of time it takes for all of the water to reach the bottom of the beaker. What does this tell you about free space transmission? Is it fast or slow?
- Using a fresh beaker, stuff a sponge halfway down the beaker. Pour the same amount of water, using the same tilt, through the beaker and again measure the amount of time taken for all of the water to reach the bottom of the beaker. What do you notice? What does this tell you about fibreoptic transmission where photons may come across obstacles to transmitting or need to bounce within the cable as they travel? Is it faster or slower than free space transmission?

TAKE THE NEXT STEP

- Using any art medium (preferable 3D), try to represent the different quantum properties you have learned about. Can you create a model which shows lasers carrying photons shooting out into space, hitting a satellite and being bounced towards their destination?
- Look into more videos about superposition, quantum computers and binary code.
- Follow up by learning how to use binary code to count.
- Watch the video of Ed Devane's Rotation Relay which uses a musical gyroscope to represent all of the quantum properties spoken about today. This gyroscope is interactive and a control board can be used to change the sounds, speed and direction of the laser. It represents photons travelling in superposition (spinning in multiple directions), teleportation (anything that happens to the main piece is transmitted to another part) and entanglement.
    - Follow the links below to look closer at superposition and quantum measurements: http://blog.cambridgecoaching.com/blog/bid/313718/Physics-Tutor-Quantum-Strangeness-Superposition-and-Measurement
        - http://thephysicsteacher.co.uk/quantum-physics-with-a-coin/

ABOUT THE ARTIST

Ed Devane is a sound artist and instrument designer based in Donegal. His work explores interactive and collaborative experiences through the media of sound and motion, where the public are invited to become active participants rather than passive viewers.

Ed has also worked with a range arts organisations to deliver workshops in instrument building and music production. Ed maintains a design studio in Donegal, Ireland, and since 2018 has been trading under the name Soniphorm, offering educational experiences and audio products. He has previously worked as a technician in NCAD Dublin and teaching assistant in University of Limerick to interaction design and music technology students.

GLOSSARY

Terms used: Photon, Superposition, Degrees of freedom, Decoherence, Fibre optic transmission, Free space transmission

Terms NOT used but can come up: We have skipped them due to the difficulty to demonstrate.

Entanglement, Teleportation

Entanglement: Can be thought of the twinning of two photons, what happens to one, automatically also happens to the other. If you measure one then you automatically measure the other. Very difficult to demonstrate in class in any meaningful way. But you could spin 2 coins, stop the first one and then make the second one look the same.

Teleportation: Entangled Photons can be any distance apart – even the other side of the universe. If you manipulate the first photon, that manipulation also happens to the other photon. This allows you to 'teleport' information from photon A's location to photon B's location as they are linked.

Project Teams

Caibleadh: 1iing Heaney with research input from Dr. Fergus McAuliffe, Dr. Mark Coughlan, Eoghan Daly and Andrew Trafford of iCRAG SFI Research Centre for Applied Geosciences.

The Invisible Made Visible: Shevaun Doherty with research input from Dr. Cormac Gahan and Dr. Aimee Stapleton of APC Microbiome. Music by Boa Morte.

Shifting Patterns of Light: David Beattie with research input from Dr. Cristina Reschke, Dr. Susan Byrne, Dr. Katherine Benson and Ciara Courtney of FutureNeuro.

Rotation Relay: Ed Devane with research input from Jerry Horgan and Dr. Deirdre Kilbane of CONNECT.

Machine's Eye View: Peter Nash with research input from Prof. Martin Mullins and Clare McInerney of Lero.

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Online Exhibition and More Information

www.sfi.ie/engagement/art-collaboration

SFI Contact Details

For more about the STEAM Art Collaboration contact primaryscience@sfi.ie or info@sfi.ie.
All SFI Research Centre contacts can be found at https://www.sfi.ie/sfi-research-centres/index.xml.

For more about the Discover Primary Science and Maths Programme visit www.primaryscience.ie or email the team at primaryscience@sfi.ie

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