Epistemic Insight

Essential Experiences in Science

INVESTIGATING BIG QUESTIONS

TEACHERS' PACK

University of Bristol
CIEC Centre for Industry Education Collaboration
University of Hull
University of Roehampton London
Canterbury Christ Church University

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TEACHER RESOURCE

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INVESTIGATING BIG QUESTIONS

The 'Investigation Cards' in this resource feature hands-on science activities that are easy for children to set up at home or in school. There are accompanying teaching notes in this booklet.

The resource also aims to encourage conversations about how science and other disciplines help us to address some real-world problems and Big Questions. Each card has a prompt to introduce a Big Question – usually on the back. This booklet includes accompanying Discussion Guides.

The appendices have student worksheets, extra information, and surveys.
If you want extra help or to share some feedback, please email **lasar@canterbury.ac.uk**

OPPORTUNITIES FOR CONTINUING PROFESSIONAL DEVELOPMENT (CPD)

Members of the research team offer CPD to teachers engaging with Investigating Big Questions to support the resource's use. CPD can include advice on planning and delivering the activities within a classroom context. Examples include advice on managing science discussions with students and ways of using pedagogical tools, such as the discipline wheel included in the resources, to investigate Big Questions. Teachers can also access webinars on Epistemic Insight. These are held regularly by Canterbury Christ Church University and focus on exploring Big Questions and using the Epistemic Insight curriculum framework in classroom practices.

RESEARCH TEAM

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ACKNOWLEDGEMENTS

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INTRODUCTION

This resource uses hands-on activities in science to prompt conversations about science and Big Questions. The materials can be used by teachers, parents or other adults with children aged 8-12 years old to enable:

- Experiences of practical science supported by an investigation card and related teaching notes.
- Encouragement for children to express their curiosity about Big Questions; Access to adults who can help to take their thinking forward, with the optional help of discussion guides.

These activities aim to increase students' understanding about science and other sources of knowledge by:

- Explaining what makes science distinctive as a discipline
- Explaining with examples that science and other disciplines can inform our thinking about a Big Question which does not have a simple agreed-upon answer.

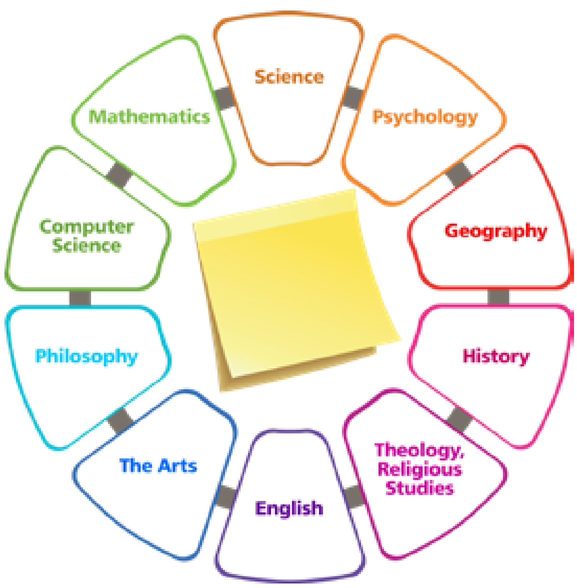
BUILDING AN UNDERSTANDING OF SCIENCE AS A DISCIPLINE ("WORKING SCIENTIFICALLY")

One of the key aims of the activity is to build student's epistemic insight (which means 'knowledge about knowledge'). This includes understanding that science is a discipline that asks and investigates questions about the natural world.

Within the science curriculum specification, pivotal phrases like **observe, observation, measure** and **natural world** are examples of what is called, 'working scientifically'. In science we ask small precise questions that we expect to be able to answer by making observations and measurements. Our first card and activity on spinners makes this its focus. Students can then compare science as a way to investigate a question with how they enquire in other disciplines such as history and religious studies. Answering a small question in science, like 'where does a puddle go when it dries up?' can inform how we think about a Big Question like, 'Will we ever control the weather?'

HOW CAN DISCIPLINES LIKE SCIENCE, HISTORY AND MATHEMATICS HELP US TO ADDRESS BIG QUESTIONS?

As well as explaining that science is a discipline that helps us to understand the natural world, this resource builds students' understanding about other disciplines (mathematics, science, history, geography, music etc). Each Investigation Card asks a question we can investigate scientifically. It also connects that investigation to one of life's Big Questions. In most cases the hands-on activity is on the front of the card and the Big Question is on the back.



Our 'Discipline wheel' (opposite) is a tool to help students and scholars to identify and discuss the ways that different disciplines interpret a question.

Talking about how disciplines can help us with Big Questions strengthens students' *epistemic insight.* This is their ability to work with one or more disciplines at a time.

BIG QUESTIONS: SCIENCE AND RELIGION

Big Questions that ask about the nature of reality and human personhood are questions where science and religion both seem to have something to say. An example is 'Why does life and the universe exist?' As you will see, on the reverse of the weather card we ask 'Does God control the weather?' This and some of the other Big Questions we cover have come from students:

> ***Does God control the weather?***

> ***Why did God make storms?***

Students of all ages tell us that they ponder Big Questions and wonder how science and religion relate. By age 13 they also say that they "know not to ask those sorts of questions" in their encounters with adults. Reasons include that the questions make adults look uncomfortable and that there doesn't seem to be an appropriate person or space in which to express their curiosity.

These questions can be hard to talk about because there are no easy answers and there seem to be many competing and sometimes contradictory approaches and responses. Key to our resource is encouraging students to ask questions and helping adults with how these questions can be explored.

The materials introduce some of the ways that scientists and other scholars respond to scientific and religious ideas. They highlight the value for everyone, scientists included, of asking questions that we cannot answer yet and may never be able to answer – as well as the value of asking questions we can investigate in science.

KEY LEARNING POINTS

Teachers should look for opportunities to apply and review some of the ideas and phrases explained in this learning sequence. What we want to show through these activities and discussions are the following things:

- Science specialises in asking and addressing small, precise questions about the natural world.
- Different disciplines have different preferred questions and can help us to answer a Big Question in different ways.
- Scientific answers inform how we think about Big Questions that cannot be fully resolved using science alone.
- Big Questions are questions that do not have simple agreed-upon answers, if we can answer them at all.
- Science, history, and mathematics are examples of disciplines or branches of knowledge. Science and religion are examples of ways of knowing. (Theology is a discipline).

EPISTEMIC INSIGHT LEARNING OUTCOMES AND OBJECTIVES

In this resource we have a curriculum guide which draws on the National Curriculum to explain how areas of knowledge relate.

LEARNING OUTCOMES	Relationships between science and religion	The nature of science in real world contexts and multidisciplinary arenas	Ways of knowing and how they interact
UPPER PRIMARY	Science and religion are mostly concerned with different types of questions, including different types of why question.	Science begins with observations of the natural world and constructing ways to explain our observations. Some methods are more scientific than others.	Science has some similarities and some differences with other ways of knowing that we learn about in school.
LOWER SECONDARY	Today we ask big questions about human personhood and the nature of reality that bridge science and religion. Some people say that science and religion are compatible and some people say they are not.	Science informs our thinking about every aspect of our lives. Some questions are more amenable to science than others. There are some questions that science hasn't yet and may never be able to answer.	A school is a multidisciplinary arena. Different disciplines have different preferred questions, methods and norms of thought.
UPPER SECONDARY	Science and religion are not necessarily incompatible.	Scientism is not a necessary presupposition of science.	Some questions are more metaphysically sensitive than others.

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SEQUENCE OF CARDS, ACTIVITIES, AND DISCUSSION GUIDES

1 Our first card **'why do spinners spin?'** teaches students about the nature of science. We notice that science can help us understand the natural world and that science uses observations to generate and test ideas.

- Students build their epistemic insight (knowledge about knowledge') when they learn that science, as a discipline, asks and investigates questions about the natural world.
- Within the science National Curriculum, key words, and phrases like observe, observation, measure, and the natural world provide examples of what it means to 'working scientifically'.
- Students can also compare science as a way of knowing, or scientific enquiry, with what it means to work as a scholar in other disciplines (e.g. mathematics, music and history).

2 Our second card **'How do clouds stay up?'** shows that two or more scientific explanations can work together to explain something more complicated in the natural world.

- To understand what a cloud is and why it stays up we need to know about several scientific ideas. These include gravity and the idea that little water droplets can be suspended in our atmosphere of air. We also need to know water forms droplets because of surface tension and that water droplets stick together.
- In the discussion guide we notice that science helps us to understand why it rains by telling us about the properties and behaviour of water, gravity and the atmosphere. Watching the weather also prompts us to ask questions that we can't yet answer – for example does it rain on lots of other planets and if so – how many? And there are some questions that are less scientific but still important or fun to ask – such as – what shapes and animals can you imagine when you look at a fluffy white cloud? Some people suppose that science reduces our wonder at the world around us by explaining what we see – but other people say it adds to our appreciation of what we're seeing and gives us more questions to ask.

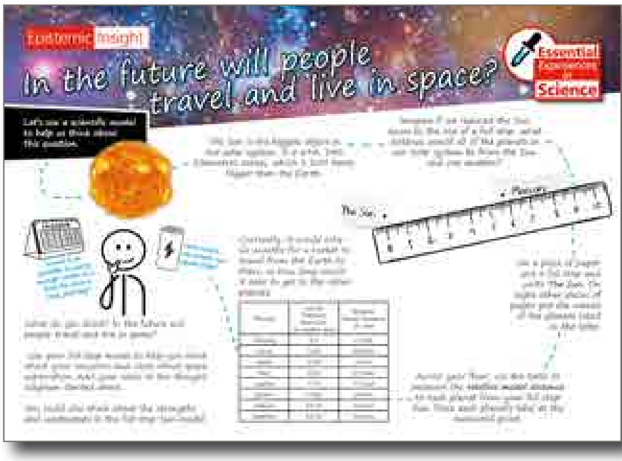
3 Our third card **'Why is the sky blue?'** explores how science encourages us to investigate ideas about the natural world that we can test with observations – and we can explain our blue sky in terms of the scattering of different colours of light.

- Looking at light through the diffraction glasses reveals the colours in the spectrum – and supports our scientific explanation of where colours come from
- The 'Perfect Planet' side of the card explains some of the ways that the Earth is 'just right' when it comes to what is needed in order to have a planet with living things including intelligent living things.
- We call on physics and biology to explain what is happening when rays of light arrive at our eyes, we can draw on psychology to explain how our minds make sense of what we are seeing, art to express our wonder at the beauty of nature and many more disciplines to help us to develop and share ideas about our colourful world.

4 Our fourth card **'How do we make sense of the weather?'** explores the weather scientifically and how we can make the predictions about the weather by looking at patterns.

- Looking at the wind using scientific methods.
- Exploring the nature of weather and how it impacts upon people and the environment.
- Opens up discussion around 'Big Questions' about the weather and whether it can be controlled by God.

5 Our fifth and final card **'In the future will people travel and live in space?'** explores space travel and how science helps us understand space.



- This activity explores the physics of the solar system and the Big Question of whether people will one day live on other worlds.
- It looks at how we can use science and history to understand how far our thinking and capabilities have progressed in a short space of time.
- It also considers how science and history ask different questions about space travel.

1 WHY DO SPINNERS SPIN?

WHAT IS THIS SESSION ABOUT?

This session aims to support students, teachers, and parents in using the scientific language of **'observe'** and **'observations'** to help students work scientifically. **Spinners focus on the exploration of the nature of science. The card illustrates how science studies the natural world and uses observations to generate and test ideas.**

Session Aims

Can students identify 'observe' and 'observations' as key to investigating scientifically?

Links to National Curriculum content

- Forces – Air resistance, friction, gravity
- Working scientifically – see lesson objectives

Support and Free materials:

One investigation card, two spinner templates, one set of teaching notes, a discussion guide, student's worksheets, and before and after surveys.

See appendices for student's worksheets.

TEACHING NOTES

These teaching notes accompany the activities and information on the card.

OBJECTIVES

- **To explain what it means to work scientifically: Science begins with simple observations made about the natural world and making sense of these observations.**
- To investigate scientifically the influence of gravity and air-resistance on the flight of spinners.
- To record, analyse and communicate observations.
- To use test results to make predictions to set up further **comparative test**s
- To identify scientific evidence that has been used to support or refute ideas or arguments

Activity 1: Hook questions to generate interest in the spinners (5-10 mins)

Look at some pictures of objects that move through the air, e.g. kites, parachutes, leaves, and seeds with wings or parachutes. The seeds on the card are from a sycamore tree. These have wings to aid their dispersal from the trees by the wind. Discuss students' ideas in response to these questions:

1. What makes a good parachute?
2. Why do people fly kites?

You can draw on students' experiences of flying with kites or playing with toy parachutes:

- What are their experiences of flying kites?
- How can we get kites to lift into the air?

Ask the students: *How can science help us to answer these questions?*

- In class, think, pair, share: Give the students 2 minutes to discuss these with a partner before feedbacking their ideas back to the whole class. At home, discuss and share ideas.

Tell the students: *Today we are going to be thinking and working as scientists. We will be using the words, observing and observations. Discuss what observation means:* To look carefully at something and describe what we notice.

Paper Race: What happens to paper falling to the ground? (10 mins)

Resources

- Two sheets of A4 paper per pair/small group

Task

Hold out a sheet of A4 paper and a rolled-up ball of A4 paper at the same height ready to drop. Discuss these questions:

- *Which of these will hit the ground first: The paper sheet or the paper ball?*
- *Why do you think this will happen?*
- *Write down your prediction on the student worksheet.*

Let the students try this activity for themselves. What do they notice? They can draw and write about their observations on the student worksheet. Remind them that scientists often experiment more than once to check their findings and record their ideas and observations. Ask them to repeat and check their results. Finally, they could scrunch the other sheet and drop the two paper balls together.

Again, ask students to predict and then *record their observations – which hit the ground first?*

Student worksheet for paper drop exercise. This worksheet goes with our spinners card.

STUDENT SHEET 1 (The Paper Drop)

1. Take 2 sheets of A4 paper (watch out for paper cuts!)

2. Scrunch one into a ball and keep the other one flat.

3. Predict what you will observe when you drop them from the same height.

4. Observe what happens and see if you were right! (Do this a few more times – is the outcome the same?)

4. Record your observations after each drop.

You are about to drop a scrunched up and flat sheet of paper – which will hit the ground first, what's your prediction?

Now try the investigation twice and write down your observations

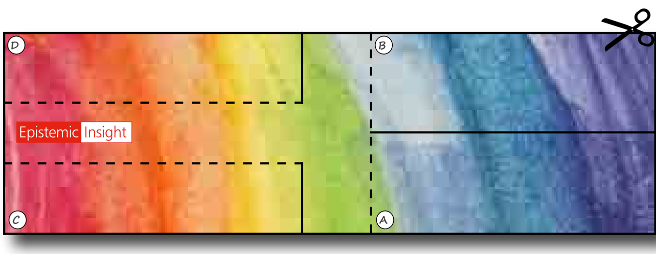
Try dropping two scrunched up balls, what do you observe now?

What have you found out?

Activity 2: Spinners (15-20 mins)

Resources

- Two copies of the spinner template per child
- Scissors
- Paperclips



Task

A) Guide the students through the process of cutting and folding the template to create a spinner – or prepare the spinners in advance. For each spinner:

- Cut out the template, cutting along the solid lines.
- Fold section C and section D along the dotted line
- Fold section A along the dotted line towards you
- Fold section B along the dotted line away from you

Students can drop their spinners and observe what happens. Give each student: 2 spinners and 4 paperclips. Invite them to compare what happens to the spinners. If they don't try it themselves, suggest they put the clips onto one of the spinner's tails. Use these types of questions for discussion:

- *Does the colour of the spinner affect how if falls?*
- *Does the number of paper clips affect how it falls – does it change the spin, the speed that it falls or both?*
- *What else might affect how the spinner falls?*

Invite the student to make sense of their observations on the student worksheet: Can they infer patterns from their observations? By adding more paper clips, the spinner spins more quickly and also falls more quickly. The colour does not affect how the spinner falls.

Student worksheet for Spinner Activity

Investigation:

1. Can you change how fast a spinner spins?
2. You will need two copies of the spinner template.
3. Cut them out, cutting along the solid lines only (careful with the scissors!)
4. Fold along the dotted lines (section A folds towards you, section B folds away)
5. Explore dropping the spinners and observe them falling and spinning. How many rotations do they do. Is the result always the same?)
6. Record your observations in the table on the next page (first box)
7. What happens if you add a paperclip to one spinner (at the bottom, like in the photo) will it spin faster/slower/the same/different direction? Predict what you think you'll observe.
8. Now try it out!
9. What happens if you add MORE paperclips?

Investigate	General observations	Comparison – which hit the ground first, did one spin faster?

Encourage them to notice that a spinner can behave differently each time it drops, even if they change nothing.

Students are **not conducting a 'fair test'** but are instead, **'making observations to infer patterns'**. Adding one paper clip adds weight to the spinner and influences the slope of the wings. There can be several underlying changes affecting how the spinner falls.

B) Next, challenge students to apply the knowledge that they have gained to make:

i. a spinner that falls slowly
ii. a spinner that falls quickly
iii. a spinner that spins around fast.

C) Set up and conduct comparative tests: Investigate different sizes and shapes:
Students can cut or fold the wings of their spinners which they may not want to do. If they decide to go ahead, ask students: *Now we want to know whether changing the spinner's wings' size affects how it falls. What do you think?*

Adjust the spinners by size (cutting a larger or smaller spinner from the paper template). Adjust the design (change the wing width/length), add weight (paper clips), or the height it is dropped. Some of these changes can't be undone, e.g. if children crease or cut the wings to make them shorter.

- Spinners will fall *more slowly* if they have larger wings. Larger wings increase the surface area, and there is more air resistance.
- pinners will fall *more quickly* to the ground if the wings are made shorter or narrower (with less surface area).

D) Explanation: Why do spinners spin?

- Science helps to explain how objects, such as parachutes and winged seeds move through the air. It isn't easy to explain. Scientists work to produce better descriptions and explanations of how things move through the air. University courses teach this topic, called 'aerodynamics'.
- The force of gravity pulls the spinner down toward the earth's centre. Air resistance acts upon the spinner as gravity pulls the spinners down. Air resistance is a type of friction force, which tends to oppose or impede movement. Air resistance slows down the spinner as air pushes upwards on the spinner's wings.
- The spinners are similar in some ways to a sycamore seed. Broader or longer wings provide an increased surface area. The wings of spinners are not always symmetrical. Sometimes they are at an angle. Sometimes they are not opposite the centre point. It means forces acting on each wing are uneven, and therefore the spinner twists round.

Activity 3: What did Galileo think about things that fall?

Students can research Galileo's ideas about how things fall by dropping a range of objects. Galileo realised that without air, objects with different masses accelerate at the same rate when dropped. They hit the ground at the same time. The best evidence that supports Galileo's idea was David Scott's hammer and feather investigation on the moon. He was an Apollo astronaut. You can watch this experiment on YouTube: **www.youtube.com/watch?v=5C5_dOEyAfk**

See also:
www.pbslearningmedia.org/resource/nvmm-math-fallingbodies/galileos-falling-bodies

Plenary (5-10 mins)

Discuss what the students have learned about how science answers questions. *(Scientists answer questions by making observations and making sense of these observations).*

Revisit the questions from the beginning of the lesson. Can they use the knowledge they have learned about spinners to answer these questions? Ask the students: *Which of these questions can be answered by science? What evidence do they have to support their ideas?*

A. What makes a good parachute?
B. Why do people fly kites?

Q1: What makes a good parachute?

Science helps us to observe the effects of air resistance on falling objects. We can use what we have learned from our observations to design safe parachutes. Why do parachutes come in various styles and colours? The size of the canopy influences the rate of fall. Interestingly, parachutes may swing as they fall. Putting small holes in the centre can allow the air caught under the canopy to escape more smoothly and create a smoother flight.

Did the colour of the spinner affect the way it fell? Are parachutes different colours for non-scientific reasons? (e.g. Art – to appreciate its beauty and colour).

Q2: Why do people fly kites?

Science can help us design and make kites that fly. A large surface area helps catch the air and push the kite upwards into the air).

Science does not answer the question: Why do people fly kites? What other disciplines could help us answer this question? History (who first invented the kite?); Sport (kite-surfing is a fun water sport activity); Geography (how does the weather affect kite flying?). Some photographs of these activities would aid the discussion.

Extension activities

Students can design and make parachutes using various materials, string, tape, and small weights. The challenge can be making a parachute that always opens, falls slowly has a gentle landing.

They might also like to design and make paper planes and explore their flight.

DISCUSSION GUIDE

Talking about Science with Students

This discussion guide offers suggestions about how to talk with children about science and addresses some of the following questions:

- **What makes an effective discussion in science?**
- **How can we enable the student's awareness of the value of discussing their ideas and the importance of talk for their learning?**

ENCOURAGING EXPLORATORY TALK

We can provide students with Big questions, exciting experiences, and valuable resources. Still, we also need to encourage them to discuss what they are doing throughout the experiences on the cards to maximise their learning. Exploratory talk can enable students to share their ideas and reasoning about the activities and make sense of the natural processes and events they encounter in our world.

By enabling students to present and defend their ideas, teachers can establish limits in their understanding. Teachers can both elicit and challenge any misconceptions students might hold about the objects, processes or events under investigation. They can challenge students' thinking, help them make links between ideas and their experiences, and advance their understanding of science concepts.

In pairs, small groups or whole-class discussions, an adult can ask questions that encourage students to make sense of their experiences. They can encourage them to challenge others' views respectfully. Students can explain their ideas to others. They can listen and help clarify each other's thinking. They can share ideas about how to investigate scientific questions together. Essential questions the teacher/adult might ask include:

- *Can you explain what you are doing?*
- *What are you thinking?*
- *Why do you think that?*

Such questions invite students to articulate their ideas using everyday language, listen to alternative views, consider new ideas and even change their minds. The cards and teacher's notes provide various questions designed to promote discussion. Teachers play a central role in fostering helpful ground rules for productive, on-task talk.

Whereas whole-class discussions can motivate students and establish the expectations for learning, adult interaction with students in smaller groups can help them think aloud during the tasks.

ESTABLISHING HELPFUL GROUND RULES

By engaging students in devising the ground rules for science talk, they can appreciate its importance in their learning. These rules can be recorded, displayed, or used to remind students of the expectations. Examples of ground rules include:

- Listen attentively to ideas, reasons, and evidence
- Ask questions
- Respond to each other's questions
- Challenge each other's ideas respectfully
- Enable everyone to speak
- Help each other to agree on our actions

USE OF THE 'DESCRIBE-EXPLAIN STRATEGY'

The premature use of scientific vocabulary can be confusing to students if used out of context or without the scientific observation, discussions and reasoning that make the terms understandable. The 'describe-explain strategy' entails students first describing what is being observed and, secondly, explaining why it has happened (Wenham and Ovens, 2010). The first task on the card asks students to watch how paper falls. The next entails observation of spinners falling to the ground.

In both cases, the tasks invite students to describe what happens before considering scientific explanations. Describing how paper falls to the ground may not involve the use of scientific vocabulary or concepts. Teachers can fully explore the concept of forces and the scientific language concerned with forces after discussing how objects fall to the ground. Teachers can ask questions about the forces involved:

- In what direction did the force act?
- Do you know the name of the force, which makes things fall downwards?

Introducing scientific vocabulary is essential in enabling students to develop the cause and scientific explanations for their observations. If students use scientific language incorrectly or prematurely, as a teacher, you can challenge their ideas. Teachers can go back to asking the students to test their ideas using observation and evidence collection. For example, students may predict that the paper falls to the ground due to gravity or that air-resistance may be involved when asked, 'What do you expect to happen?' The answer, 'it falls to the ground due to gravity,' does not mean that the students have a complete understanding of what is happening. Detailed observation and explanation can facilitate their growing knowledge. Teachers can encourage students to reflect further and extend their existing knowledge of forces. For example, does gravity act at different stages of the process: before the object's release, during its flight and when it hits the ground?

For example, students may predict that the paper falls to the ground due to gravity or that air-resistance may be involved when asked, 'What do you expect to happen?' The answer, 'it falls to the ground due to gravity,' does not mean that children have a complete understanding of what is happening. Detailed observation and explanation can facilitate their growing knowledge.

WHEN AND HOW TO INTRODUCE SCIENCE VOCABULARY

The National Curriculum establishes the scientific vocabulary and concepts students should be introduced to at different ages. The challenge is deciding when to teach the correct language and the required detail. Generally, scientific language can be introduced when students need to explain something they experience. They can then link the concepts of gravity and air-resistance to the objects in their investigation. When students use scientific language to form explanations, this can lead to them asking new questions for investigation and them developing a hypothesis for testing. For example, they may begin to devise ideas about what influences the air-resistance acting on the falling object, such as the paper's surface area of the spinner's wing-length. Teachers can help students discuss the questions:

- What new questions come from the changes in our thinking about falling objects?
- How can we check our understanding?
- How do we get to know that our ideas are right?

The students can devise practical tests to see if their ideas are right. Through further discussion, the teacher can help students think about what they need to do to test their ideas, construct a suitable science question, or simplify their tests.

A teacher plays a substantive role in enabling students to understand the meaning of the words used to describe scientific inquiry, such as ‘prediction’, ‘observation’ and ‘evidence’. It is helpful if you can give simple definitions of these terms. For example, predictions are what we expect to happen in the future. They can be linked to the hypothesis if we can say why we expect that to happen. You can also model such terms whilst interacting with the students and provide them with examples of such terms.

Thank you to our Advisor Dr Nidhal Guessoum
(American University of Sharjah)

2 HOW DO CLOUDS STAY UP?

WHAT IS THIS SESSION ABOUT?

This session aims to support students and teachers in using the scientific language of 'observe' and 'observations' to help students to work scientifically.

Session Aims

- Can students identify 'observe' and 'observations' as key to investigating scientifically?
- To understand that science begins with simple observations made about the natural world.
- To investigate the properties of water droplets.

National curriculum content

Water cycle

Support and Free materials

1 Investigation card, pipette/straw, 1 set of teaching notes, a discussion guide, two student worksheets.

TEACHING NOTES

These teaching notes accompany the front of the card.

Students will increase their understanding of clouds and rain by observing the properties of water and applying their observations to their experience of weather.

OBJECTIVES

- To understand that science begins with simple observations made about the natural world.
- To investigate the properties of water droplets.

Prior knowledge and skills

- Students will have an understanding of the properties of liquids
- They will understand that gravity is a force that pulls objects to Earth
- They will be able to use a pipette or straw to make water drops

Vocabulary

Water, gravity, force, property, liquid

Observing water droplets

Invite students to speculate what might happen if they were to place a drop of water onto a penny.

- Would it cover the surface of the penny?
- Would it stay on the penny?
- What shape would it be? Ask them to draw the penny after the water has been dropped onto it.

Ask them to use a pipette or drinking straw to place a tiny drop of water onto a penny.

- What do they notice about the size and shape of the water drop?

- Is it the same as what they were expecting?
- Thinking about what they know about the properties of liquids, were there any surprises?

Students may be surprised by what they notice as they have learned that liquids form a pool, not a pile and yet the water drop on the penny is not completely flat. Let them know that scientists always have to be very observant to ensure that they look carefully at the phenomenon around them rather than what they expect to see.

Now ask them to predict what will happen if they place another water droplet close to the first one, before testing their idea.

- What do they notice?
- How many drops of water are on the penny now? *(if the two drops were close enough there should now be one larger drop on the penny rather than two smaller ones).*

Explain that scientists use observations of things that they can see to explain and to predict what they cannot see. They also use information from different sources to increase their understanding of things that they cannot directly investigate.

Ask students to share everything that they know about clouds.

- *What are they made of?*
- *What is the effect of gravity on clouds?*
- *What is the effect of gravity on raindrops?*
- *What changes must happen to the water in the clouds?*

Support the students to understand that water droplets in clouds are so tiny and light that gravity has a marginal effect upon them. However, as they bump into each other they **coalesce** (come together) just as the drops of water did on the penny. As this happens, they become larger and heavier until the effect of gravity means that they fall to earth.

Explain to students that scientists often combine observations that they **can** make with those that they cannot, to understand more about how the world works. For example, they can measure how much a light gets dimmer when an object passes in front of a light source. For example, some scientific equipment is so sensitive that it can measure how much dimmer a streetlamp gets when a fly flies in front of it. Scientists can then use this information to measure how the light from distant stars gets dimmer from time to time and use this to work out the size of planets passing in front of it. The planets are far too small to see from Earth, even with the best telescopes, but scientists know that they are there due to these measurements.

Taking it further

- Ask students to predict how many water drops they could fit onto a penny and then to test their predictions (this is also a good opportunity to practice their fine motor skills using a pipette or straw).
- Invite them to look out for water drops in their environment for example on spiders' webs, on plants after rain, stuck to the side of the sink etc.
- Another opportunity to use their powers of observation would be to ask students to draw what they think a candle flame looks like and then to watch one very carefully and to talk about what is different from the appearance of the flame to what they drew. Some students may not want to look at a candle flame. In that case, cut an orange in half and ask them to draw what the insides of an orange look like – before and after they observe it.

- Challenge students to look out for other examples of things that do not look exactly as they expect. You could tell them that scientists and artists have this in common. Artists also look very carefully at the world around them and notice things that other people might miss.
- Generate a list of new questions for scientists to investigate such as, does it rain on other planets – why or why not?

DISCUSSION GUIDE

Does science make the world more wonderful or less wonderful?

You could read this discussion guide with students and ask them what they think. Or you could read it to inform the questions and ideas you explore with students in a conversation.

What is a cloud made from? Why does a cloud stay up? Why do clouds give us rain? Here's what we know from science:

- A cloud is made from billions of tiny water droplets. They are held up because there's a blanket of air around the earth.
- The water in a cloud comes from the seas, rivers, and puddles on the ground – when water evaporates. At first you can't see the water in air. Air can act like a sponge and soak up invisible water vapour. If the air is warm it rises. It's colder higher up and the water vapour condenses into tiny droplets.
- Winds blow the clouds, and we see them move across the sky. The droplets join up inside the cloud. Gravity pulls them down once they are too big to be held up by the air.

Science helps us to understand why it rains by telling us about the properties and behaviour of water, gravity, and the atmosphere.

Sometimes people say that science reduces or replaces the beauty of nature by explaining away the mystery.

WHAT DO YOU THINK?

Does a scientific explanation for why clouds stay up mean we stop marvelling at the shapes and colours of clouds?

Or is a cloud more amazing now that we understand the science of what it takes to make clouds?

WHAT DO YOU SEE IN A CLOUD?

When I look at a cloud, I know I am seeing billions and billions of tiny droplets of water, held in the sky by our atmosphere of air. But that's not all I see when I look at a cloud. Have you looked at the clouds and imagined you see animals?

What animal do you see in this cloud if any?

As we look at the world around us, we start to ask questions about what we see. Sometimes the answer that first comes to mind is a good enough answer to have.

DIFFERENT TYPES OF QUESTIONS

Sometimes you want a more scholarly answer – an answer that you can support with good reasons. Science helps us to investigate questions …

Can you think of a question we can investigate scientifically? If a question is a good one for science, we could do our own scientific investigation or we could find out whether someone has investigated the question already. If we want to know why it rains, we can ask a scientist or look in a science book.

Some questions are good ones for science but science hasn't answered them yet. For example, here's a question that scientists want to carry on exploring and investigating: "Does it rain on other planets and if so which ones and why?" Can you come up with some more questions for science that haven't been answered yet?

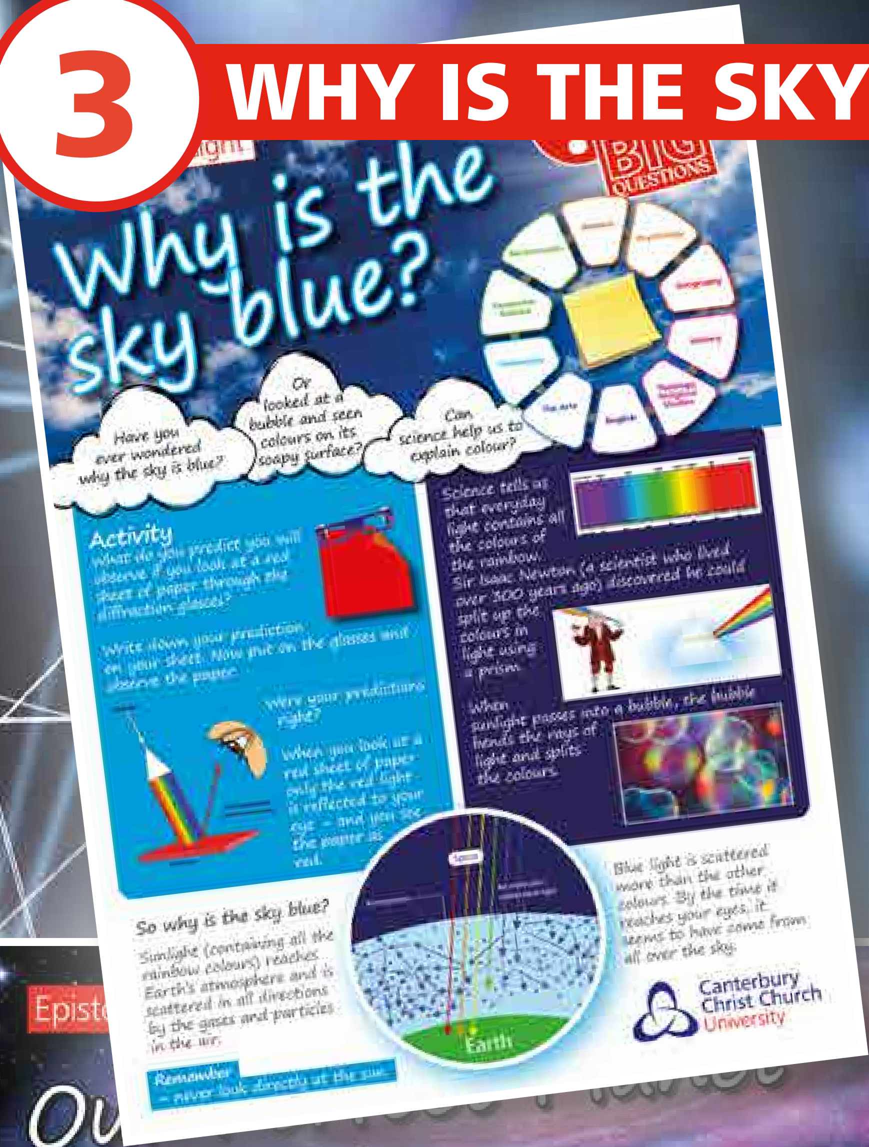
Finally – some questions cannot be solved by science alone. We can draw on science and other disciplines to help us but perhaps we will never have a final agreed answer.

In this investigation card and Discussion Guide we've talked about several different types of questions:

- Questions that have instant answers.
- Questions we can investigate and answer scientifically.
- Questions we can investigate scientifically but we cannot answer yet.
- Big Questions that we may never be able to answer but science and other disciplines inform our thinking.

I wonder what question the person in the picture is asking – can you surround her with thought bubbles, each with a question! Try to have examples of different types of questions. For each one, can you say which kind of question it is?

3 WHY IS THE SKY BLUE?



WHAT IS THIS SESSION ABOUT?

This card explores the idea that science adds to our sense of awe and wonder about the universe. The sciences and the humanities make sense of a 'why' question in different ways. Science asks 'why' because we want to understand how nature works. Religion asks why to ask – 'why is it so?' For those with a religious faith the answer might be 'because this is how God made it'. But the interesting part is to wonder – why is this the way that it works?

Session Aims

- Encourages investigation about the natural world that we can test with observations
- Explain our blue sky in terms of the scattering of different colours of light.
- Looking at the light spectrum scientifically through use of diffraction glasses.
- Understand how other disciplines might understand experience of colour differently.
- To recognise that Earth is 'just right' when it comes to what is needed in order to have a planet with living things.

National Curriculum content

Light

Support and Free materials

1 Investigation card, diffraction glasses, coloured card, 1 set of teaching notes, student worksheets, and a discussion guide.

TEACHING NOTES

These teaching notes accompany the front of the card.

Students will increase their understanding of light by observing some of its properties. They will begin to understand that modern science builds upon work done by scientists in the past.

OBJECTIVES

- To understand that science begins with simple observations made about the natural world.
- To investigate the properties of light.

Prior knowledge and skills

- Children will know that light is reflected from surfaces
- They will know not to look directly at the sun

Vocabulary

light, dark, reflected

Resources

Diffraction glasses, red paper, white paper, black paper.

Thinking about rainbows

Invite students to talk about what they know about rainbows

- In what weather conditions are they likely to see a rainbow?
- Can they think of any other times that they have seen rainbows?

Situations that they might mention include days when there is both rain and sun, the surface of bubbles, and oily film on water or water squirted from a hose or water sprayer on a sunny day. They might also mention prisms if they have ever seen these.

Experiencing rainbows

Give students the opportunity to make rainbows. If you happen to have prisms in the science cupboard you could get them out, but blowing bubbles or spraying water would be an equally valuable experience.

Challenge students to tell you what they know about the reasons that they see rainbows.

- What are rainbows made of?
- Where do the colours come from?
- Are the colours there when we can't see them?

You could tell them that light is actually made up of all of the colours of the rainbow. However, when they are mixed together all we see is white light. Reassure students that this is a difficult idea to understand and they are not expected to understand it in KS2.

However, you can also tell them that the scientist who first discovered that light was made up of different colours was called Isaac Newton. More than 300 years ago he split light using a glass prism and was able to explain why this had happened. Today we still admire Isaac Newton for the wonderful discoveries he made and scientists today still use ideas that he invented when they do cutting edge science such as sending a mission to Mars.

Isaac Newton said.

"If I have seen further, it is by standing on the shoulders of giants"

Invite students to explain what Isaac Newton might have meant when he said this.

- What was he talking about?
- Did he literally stand on someone's shoulders?
- How might scientists today stand on the 'shoulders of giants'?

Make sure that students understand that Isaac Newton was talking metaphorically and was referring to scientists and mathematicians of the past whose work meant that he didn't need to start from scratch but could build on their discoveries. Likewise, scientists today don't have to work out everything that Newton discovered but can build upon his discoveries to do amazing things including the mission to Mars.

Exploring the diffraction glasses

Let students try on the diffraction glasses and talk about what they can see.

- What can you see?
- What do you think is happening?
- Where is the light coming from?

Invite students to use what Isaac Newton discovered about light to explain what they can see.

Support them to understand that the glasses are splitting the white light that is around them into its separate colours. Remind them that light is being reflected off all of the different surfaces around them, which is why we don't need the lights on indoors on a sunny day, even when we cannot see the sun. You might also need to remind them that light travels in straight lines.

Talking about colour

Explain to students that coloured surfaces absorb some of the colours in the light rather than reflecting them all. For example, grass absorbs all of the colours except green, so it only reflects the green light back for us to see which is why we see grass as green.

- What colour is being reflected from this blue book?
- Can you explain what is happening?

Making Predictions

Explain to students that you are now going to challenge them to use everything that they know about light to make a prediction. Show them a piece of red paper and ask.

- What do you think that you will see when you look at this using the diffraction glasses?
- Why do you think that?

Give students a chance to test their ideas. Support them to understand that they only see red light because all of the other colours of the rainbow have been absorbed by the red paper.

Applying what they know

Now ask the students to talk about the sky.

- What colour do they see?
- Why do they think this is?

This is a bit harder to explain as in this case all of the light from the sun passes through the sky. However, although all of the different colours are scattered as they are reflected by the gasses and other particles in the air blue light is scattered more which means that the whole sky appears to be blue.

Taking it further

- Ask students to predict what will happen if they use the diffraction glasses to look at purple paper?
- Can they explain why they think this will happen?
- What about if they look at white paper?
- Or black paper?
- What will happen if they look through them in the dark?

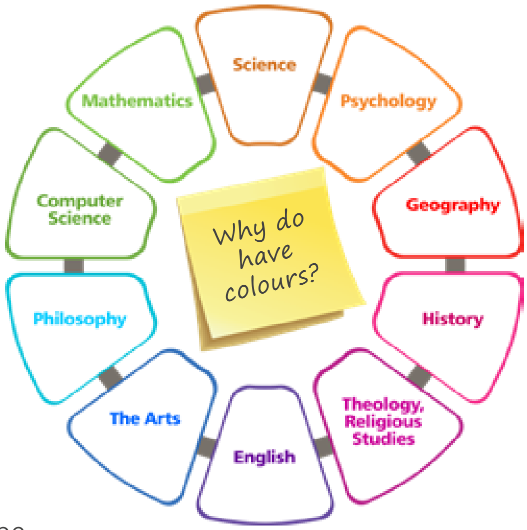
After looking at each colour let students talk about, and explain, what they see and why.

DISCUSSION GUIDE

Our Colourful World

This relates to the back of the card, 'our perfect planet'. The following discussion guide provides you with background that you may find helpful. You could read it with students or use it to inform the answers you give and questions you ask in a conversation.

WHY IS THE SKY BLUE?



The discipline wheel helps us to look at this question from different disciplines. Here are some more examples:

- **The Arts** – How do artists communicate and draw attention to an idea or view using colour? (e.g. when painting a stormy sea or a sunny beach)
- **History** – How did people in the past use colourful clothes to express their identities? (e.g. purple/red were worn by royalty as they were expensive)
- **Psychology** – how do we use colour to try to influence our moods (e.g. red is linked to stimulating anger, green is calming, yellow is happy and bright).
- **Computer Science** – How do computer programmers code for different colours? (e.g. FF0000 = red).

Questions that are good ones for Science are those that can be answered by observations of the natural world. For instance, good questions for science to answer are: 'why is the sky blue?' or 'why do I see rainbow colours through a glass of water/a bubble on a sunny day?'. Scientists have observed the splitting and scattering of colours in light.

Science is a discipline that is primarily concerned with knowledge. Religion can include a range of activities such as singing, ceremonies and prayer. But religions also ask questions about our world. Religious questions include what do we mean by rightfulness, how should we behave and what is the meaning of life. Theological questions ask about the nature of God or gods. Religious texts and artworks often explore these questions using symbols and metaphors. Scholars studying religious texts could ask questions such as, what is the meaning, purpose or symbolism behind a story, situation, or phenomenon. For instance, 'how do religions use colour in different ceremonies?' and 'Why do colours exist – at all?'.

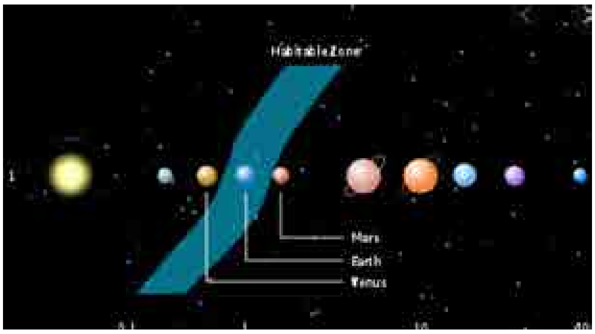
Why is this important?

A conversation about the types of questions that each of our disciplines ask – is a chance to talk about why science seems to have 'definite', agreed answers but religion doesn't.

Help students to notice that scientific questions are questions about the observable world – so a type of question where we can expect everyone to (eventually) get to the same answer. But religious questions are often questions about what something means and what we should do – so types of question that usually depend far more on who we are, where we live, and what else we believe about ourselves and the world.

When your students put on the diffraction glasses, they will notice that 'rainbow colours' appear when they look at a room light – or at something white in front of a dark background (note: ensure your child does not look directly at the Sun or a powerful light source, even when wearing the glasses). This happens because usually we cannot see the colours that are contained in visible light - they're mixed together. The diffraction glasses split up (or diffract and separate) the colours, revealing them.

OUR WORLD IS PERFECT



Our planet is in what is often called the 'Goldilocks zone', meaning that the conditions on it are 'just right' for life. Earth is not 'too hot' or 'too cold', meaning that water is a liquid (rather than vapour or ice). This is important since life on earth needs water to evolve and survive.

Our location in the solar system is also very advantageous – the position of Jupiter (which has a stronger gravitational field than Earth) means that many of the meteors that would strike our planet are pulled away from Earth, towards Jupiter.

We discover that our sun and the strength of key forces like the force of gravity are just right when we study a scientific explanation of why the earth and life is here. Large stars have short lifetimes. Once they use up their fuel (hydrogen), they may expand and become a red giant or a white dwarf, in which the star cools and stops generating heat. Our star, the sun, has produced light and heat for 5 billion years providing warmth and light for living things to live and evolve.

THE BIG QUESTION OF WHY DOES THE EARTH EXIST?

How should we explain the existence of a planet – our planet – that is just right for life? This is a Big Question and it cannot be solved by science alone, nor should we expect everyone to have the same answer.

We cannot use science to 'prove' that God exists or does not exist. If we don't believe in a God then we could explain everything that is here by attributing it to chance alone. If we believe in a God who created the universe then science can inform how we think about God and God's creative work – it adds to our sense of wonder because we understand and appreciate the universe more.

It's important to understand that science and religion are not necessarily incompatible – there are many scientists with a religious faith, as well as many without. Science can enhance a person's belief in God rather than replace it. Religion has been the inspiration and motivation for many people who go into science. You will see some of their stories on the **www.neverofftopic.com** website.

4 HOW DO WE MAKE SENSE OF THE WEATHER?

WHAT IS THIS SESSION ABOUT?

The weather card that will also be included broaches Big Questions in relation to whether and ideas that weather can be controlled by / a sign from God. This will allow children to approach different disciplinary ways of thinking about the weather. The below discussion guide discusses in more detail.

Session Aims

- Students to explore aspects of the weather scientifically
- To understand that science begins with simple observations made about the natural world.
- To investigate the wind

National curriculum content

Weather

Support and Free materials

1 Investigation card, 1 set of teaching notes, a discussion guide, student worksheets, cloud chart, windsock resources.

TEACHING NOTES

These teaching notes accompany the front of the card.

Students can make sense of the weather by observing patterns in the weather over time. They can compare their observations the weather they experience with the weather forecasts on the TV or radio.

OBJECTIVES

- To understand that science begins with simple observations made about the natural world.
- To investigate the wind and explain the scientific observations made.
- To record patterns in the weather and use these to make predictions about the weather
- To raise questions about the nature of the weather and its influences on people and the environment

Activity 1: Investigating the wind

'Wind' is the movement of air within the earth's atmosphere. Students can observe, measure, and record the wind's direction and its force. The first activity invites students to discuss their experiences of being outside on a windy day and feeling the wind's force. The force of the wind is directly related to the speed of the wind. They can compare their experiences of being outside on a calm and windy day. Here are some questions to prompt discussion:

1. What is happening to the children in the photograph?
2. What evidence is there to explain that wind exists?
3. What might happen to these children on a calm day?
4. What might happen when the wind gets out of control?
5. What causes the wind?
6. What can the wind move?
7. How can we measure the wind?

Outdoors

Encourage students to raise questions about the wind. Science questions are those that can be investigated by making science observations. Here are some examples of questions to promote observation of the wind outside:

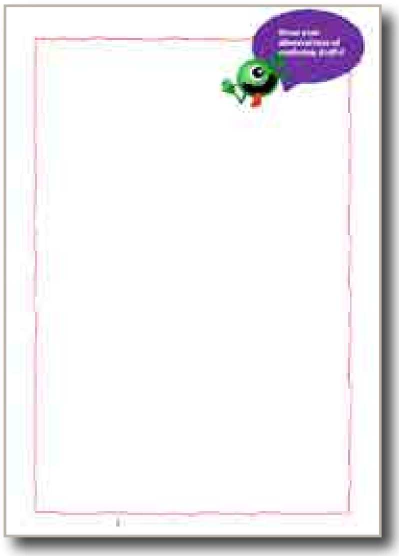
1. What does it feel like being in the wind?
2. How would you describe how it is blowing? We use lots of words to describe how the wind blows, e.g. smoothly, fiercely, or in gusts.
3. What sounds can you hear?
4. What happens when you move forwards against the wind? How does your movement change when the wind is behind you?
5. Using a large flattened cardboard box as a shield, children can walk towards the wind holding up the card as a shield. What do they notice?
6. What does the wind move? How does it move objects? Look around and record signs of the wind moving things, such as falling leaves, tree branches and seeds.

Extension ideas

Students can measure the wind's direction by finding out which compass point the wind blows from. You can mark the compass points on the playground using playground chalk. Students can investigate whether the wind's direction changes during the day.

Students can investigate which objects the wind can move and how it moves them. Examples include a paper cup, pebble, feather, flag or even tissue paper kites or paper planes. They can decide how to record their observations.

Activity 2: Exploring drafts



The picture illustrates how students can use a strip of paper (a flap) stuck to the end of a pencil to explore drafts. A draft happens because colder, denser air moves towards warmer, thinner air. The door needs to be left open before conducting the task. Here are some questions to stimulate observation and discussion:

1. Which way does the paper move?
2. How much does it move?
3. Which room has the warmer air in it?
4. Why do you think the paper moves?
5. What happens to the flap if the door is open wider?

Students can draw pictures to explain their observations. The movement of the air causes the paper flap to move. The exploration of drafts can help students understand what causes the wind. The sun heats some parts of the earth's surface and the air above it more than others. Movement of the colder denser air to move towards the warmer, less dense air creates the wind.

Activity 3: Thinking like a scientist: Predicting and recording patterns in the weather

By observing and recording patterns in the weather, we can begin to make predictions about its outcomes. They can also listen to weather forecasts and compare them to their observations of the weather in terms of the data they collect. They can invent symbols to record changes in the weather over time and make weather forecasts.

A thunderstorm is an interesting pattern in the weather. Students can observe these. When do they hear and see thunder and lightning?

Measuring wind direction using the windsock

Windsocks come in all shapes and sizes. Students can use the windsock to measure the speed and direction of the wind. They can also make their own using recycled materials: cups, tape, paper streamers. The wind's direction can be seen when the wind blows into the sock's enlarged open end. If the sock points to the west, then the wind comes from the east. If the sock flaps gently, then there is a light wind. If it sticks out horizontally, then the wind is strong. It is interesting to investigate whether the hole is needed for the wind to blow through the sock.

Wind speed is directly related to the force it exerts on objects. We can see the destructive effects of strong wind. Francis Beaufort devised a scale to measure the wind's strength (force 0 to force 12). A hurricane is force 12. The shipping forecasts use this scale to predict the effect the wind at sea.

Students can design a Beaufort Scale using their own symbols or pictures to illustrate the wind's effects based on their observations. They can also observe and record what the sock looks like at different times and in different conditions.

Modelling: Students can model being moving air and model winds of different types, speeds, and directions. They can explore what might happen to trees and objects in the wind's path.

Activity 4: Using a Big Question to investigate the weather: How does the weather influence our lives?

Scholars from different disciplines are interested in the ways weather can affect our lives. From a science perspective, we can use our predictions about the weather to enhance the quality of our life. We can plan beach trips or days out. A gentle breeze helps to keep us cool in hot weather, or we could sail a boat on a windy day. We can also take action to protect ourselves against the effects of severe weather.

- Invite students to discuss how different weather conditions can make them feel and behave. Examples include storms, thunder and lightning, heavy rainfall, hot sunshine, strong winds or gentle breezes. How do changes in the weather influence their playtimes outdoors?
- Using photographs or film-clips, students can analyse the damage caused by tornados, hurricanes and extreme flooding on the environment (buildings, trees and the sea). They can discuss how humans seek to protect themselves from severe weather.
- Using a table, such as that below, students can compare two or more weather types. They can draw or write about how this weather makes them feel. They can consider any dangers associated with these conditions and how humans might protect themselves from harm.

A table to show how the weather influences my life

	Thunder and lightning	Hot sunny weather	Severely windy weather	Snow and ice	Heavy rainfall and flooding
How does the weather make me feel?					
Are there any dangers?					
How can I protect myself?					

See separate student worksheet where students can fill out this table.

DISCUSSION GUIDE

Understanding and Controlling the Weather

The back of the card is focused on a 'Big Question' – i.e. 'Does God control the weather?'. The following discussion guide provides you with background that you may find helpful. You could read it with students or use it to inform the answers you give and questions you ask in a conversation.

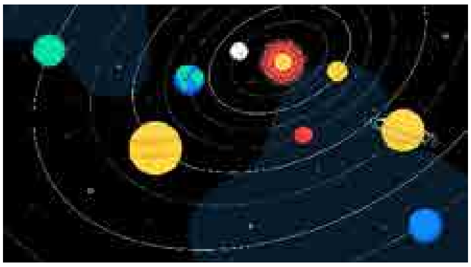
People have wanted to understand and control the weather for centuries. We depend on rain to water crops and fill reservoirs. We need sunlight for warmth and to grow plants. A favourable wind can help us to cross an ocean, but bad weather can destroy homes and lives. No wonder we want to know how the weather works. In science, we observe natural phenomena and look for patterns which we try to explain. In some religious texts the universe is God's creation, and the weather is often seen as part of a conversation with God. In that case, surely the 'best' way to get good weather…is to pray?

PROBLEMS FOR SCIENCE AND RELIGION

These pictures from science and religion seem difficult to combine: If there is a God who controls the weather then why does bad weather happen? If God is just, then why do floods happen in poor countries? And why do good people's homes burn in a forest fire? If I pray for rain but my neighbour is praying for sunshine, whose prayer will be heard? When is thunder or a rainbow a sign from God and when is it just 'weather'?

TWO BIG IDEAS

Scientists and theologians who write positively about science and religion say it helps to start with some big ideas. One of these big ideas is that God created the Earth because God wants a world where people interact with each other and with God.



Johannes Kepler was an astronomer and theologian about 400 years ago. Kepler describes a personal relationship with God where God steers his path towards science. From his observations of the planets, Kelper worked out that they move around the sun in elliptical (oval shaped) orbits. Kepler describes science as like *'thinking God's thoughts after him'*.

If there is a God, then God made the water cycle to bring water to the different parts of the land and God made a planet on which the weather has variation and unpredictable events. And storms are part of that creation. So, God didn't make storms while the rest of the weather is down to nature – God made nature and one of the characteristics of nature is that it produces storms.

Some argue that God (if there is a God) has given us the ability to investigate scientifically so that we can appreciate how much it takes to make a planet and understand why our planet is a place where there can be good and bad weather. Since we can understand the patterns in nature through scientific enquiry – we can use this to make our lives better (e.g. to prepare for a storm).

Many scientists with a religious faith today say that God sustains patterns of nature that make life possible. The water cycle is an example.

When water evaporates, it forms a gas called water vapour. The vapour movies into the air, leaving behind any dirt and impurities. Once the water vapour moves to a colder area, higher in the atmosphere, it forms droplets. These droplets gather to form bigger droplets and then fall as rain. Some rain waters the land, some runs into rivers, and some of it fills our reservoirs.

Although through using science we can find these underlying patterns in nature – there is also variation. So, whilst understanding the water cycle helps us to explain why it rains, we also know that every rainstorm will be different to the last. If there is a God, then it seems both patterns and variety are important in God's creation.

MAKING OUR LIVES BETTER

Another big idea is that we can use our knowledge of the patterns in nature to make our lives better. Professor Bob White is a geologist and Christian who writes about natural disasters. He highlights that we can prevent a lot of human suffering by changing how we plan and build our homes. We have a responsibility to use this knowledge wisely and fairly. Similar points are made by people with and without a religious faith.

CAN THE WEATHER GIVE US SIGNS FROM GOD?

What about the weather – day to day – and the idea that the weather can be part of a personal conversation with God? One suggestion is that God knows each of us very well and times when to speak to us and what to say. Some say that God can also guide us to be in the right place at the right time, to see something, or take advantage of something unusual.

'If God controls the weather and makes storms because he's angry, what's he angry at? Us?'

God (if there is a God) is present in the events of nature, and in religious texts there are stories where God draws attention to something natural and makes a point – e.g., drawing attention to the rainbow.

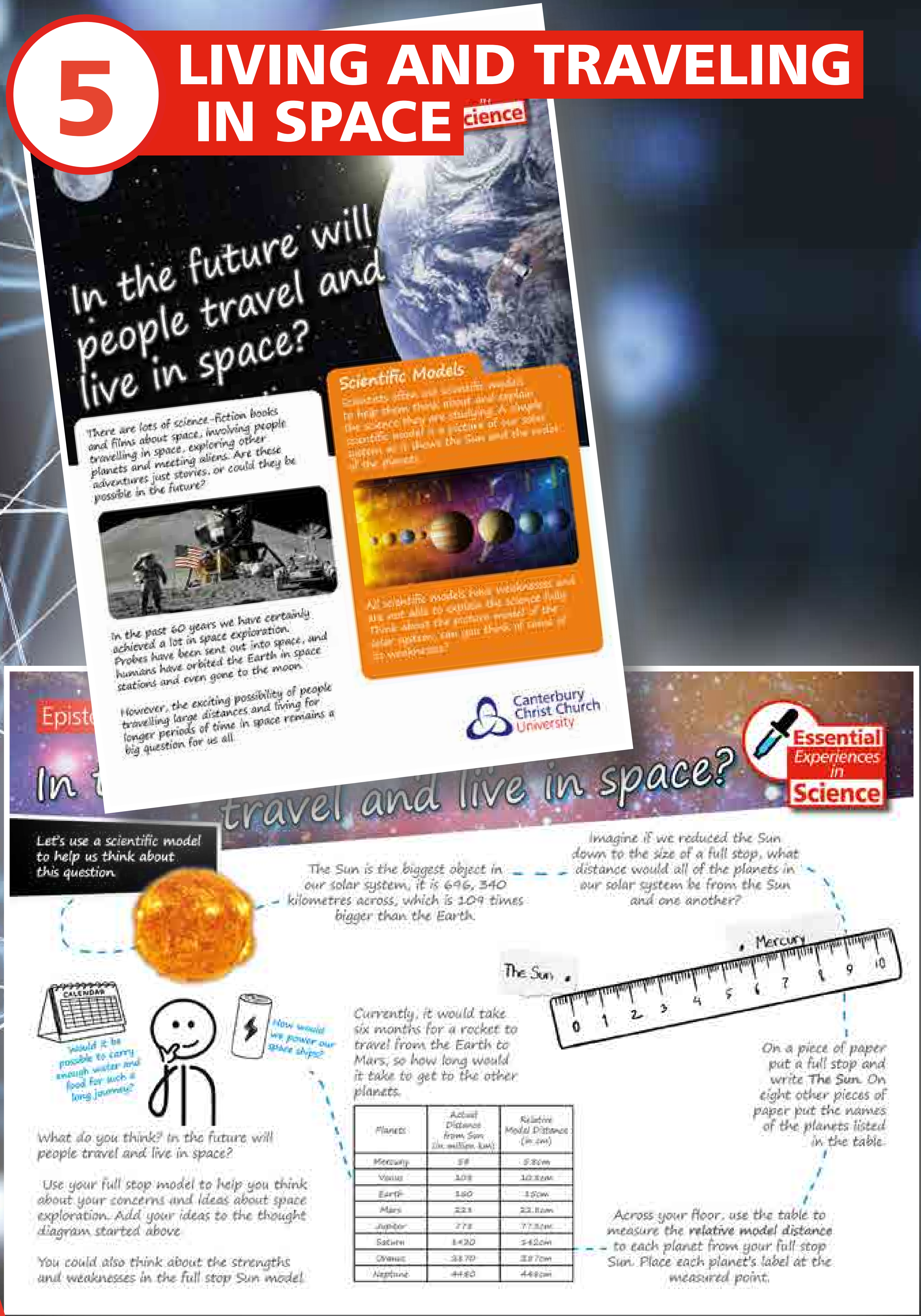
There are also stories where God has brought people to a place at the right time – e.g., the crossing of the Red Sea. But there are also stories of God saying we should not just look to the weather to 'read God's thoughts' – but Elijah finds God in a small voice rather than through extreme weather. And in Job 37-38, we are told that we cannot tell God what the weather means or tell God what is the right way for Him to communicate.

CONCLUSION

The big question is – should we only look to science to help us to understand and respond to the events in our lives? Most scholars say no – and that we will continue to call on other disciplines as well. Science, history, the arts, and theology (to name a few) help us to make sense of our experiences. At the same time, we can be grateful for science and the progress we are making in understanding nature and how it works.

Thank you to our Advisor Professor Bob White
(University of Cambridge)

5 LIVING AND TRAVELING IN SPACE



WHAT IS THIS SESSION ABOUT?

This session aims to support students and teachers in using scientific models and the scientific language of 'observe' and 'observations' to help students to think and work scientifically. This activity explores the physics of the solar system and the Big Question of whether people will one day live on other worlds.

Session Aims

- To learn that science and history are disciplines
- To understand that some questions can be answered by science and history together
- For students to explain how science and history are similar and how they are different
- Understanding that answering questions around this topic are not only to be answered by science, although it does pay its own role, questions can also bridge into other disciplines.

National curriculum content

- Science: Earth and Space – Solar system
- History of space exploration

Support and Free materials

1 Investigation card, Teaching notes, iscussion sheet, Student worksheets, ruler.

TEACHING NOTES

These teaching notes accompany the front of the card.

OBJECTIVES

- To understand science and history as different disciplines
- Recognise similarities and differences between science and history.
- Understanding that, as a discipline, science has a focus on making observations, whereas history is a different discipline which investigates a range of sources about people and events in the past.
- Think about big questions that bridge science and history.

Before they investigate, what do they already know or need to know?

Build on their existing knowledge of scientific process and understanding of evidence in history.

Before the scientific investigation make students aware that they will be using a scientific model and making observations. Throughout the scientific investigation, students must be aware that **observation** is a key method of science. The history investigation provides opportunity to compare the similarities and differences of science with another discipline.

Tell students: *"Today we are going to be working like scientists and historians! Firstly, we are going to think and work like scientists, by using a scientific model and making observations to build our understanding of Space and Space exploration. Then we are going to think and work like historians, by investigating a range of sources from the past and what they have to say about Space exploration."*

Activity One – How big is space? – Being a Scientist!

Resources – Ruler, pen, paper

Scientists use scientific models to help them explore and understand the world around us. In this activity, students will create a simple model of our solar system to help think about how big space is. They will also learn the order of the planets in our solar system. The Sun is the biggest object in our solar system, it is 696, 340 kilometres across, which is 109 times bigger than the Earth. Imagine if we reduced the Sun to the size of a full stop, what distance would all of the planets in our solar system be from the Sun and one another? In the following activity students are going to find out.

1. For the activity, students will need a piece of paper, a ruler and a pen or pencil. Tear your piece of A4 paper into 9 pieces.
2. On one of the pieces put a Full Stop and write The Sun. On the other pieces copy the names of the planets listed in the table opposite.
3. Across your floor, use the information in the table to measure the relative model distance to each planet from your full stop Sun. Place each planet's label at the measured point.

PLANETS	ACTUAL DISTANCE FROM SUN (IN MILLION KM)	RELATIVE MODEL DISTANCE (IN CM)
Mercury	58	5.8 cm
Venus	108	10.8 cm
Earth	150	15 cm
Mars	228	22.8 cm
Jupiter	778	77.8 cm
Saturn	1420	142 cm
Uranus	2870	287 cm
Neptune	4480	448 cm

Thinking about the model

Currently, it would take six months for a rocket to travel from the Earth to Mars. Using their Full Stop model of the solar system to help their thinking, ask students *"how long would it take for a rocket to travel to more distant planets, and what challenges might this present?"* Students could create a thought diagram to help their scientific thinking. How many issues and ideas can they think of?

Note: Encourage use of key scientific terms and language, particularly the key scientific method of observation. And measurement and patterns. What makes science distinct?

How big is Space?

Discuss the modelling activity – a mathematical representation. The strengths and limitations of scientific modelling and how the model needs to be consistent with our observations and current explanations. For example, the full-stop Sun model used in the activity does not show the movement of the planets.

Encourage students to think about the strengths and weaknesses in the model. Ask them how they would improve the full-stop Sun model.

- Strength being it helps explain the science through a picture of the solar system.
- Limitation or weakness is that models cannot include all the detail of the objects they represent. A model may not be accurate and can oversimplify what they are trying to investigate.

The science on the card focuses on describing the solar system – science can ask a smaller question, for example 'what does our solar system looks like?'. Consider the evidence through the lens of science: the wording of the science question, the methods used, the language and norms of thought pertaining to science. How evidence is found through prediction, testing, causation, and observation.

Support your students to identify how

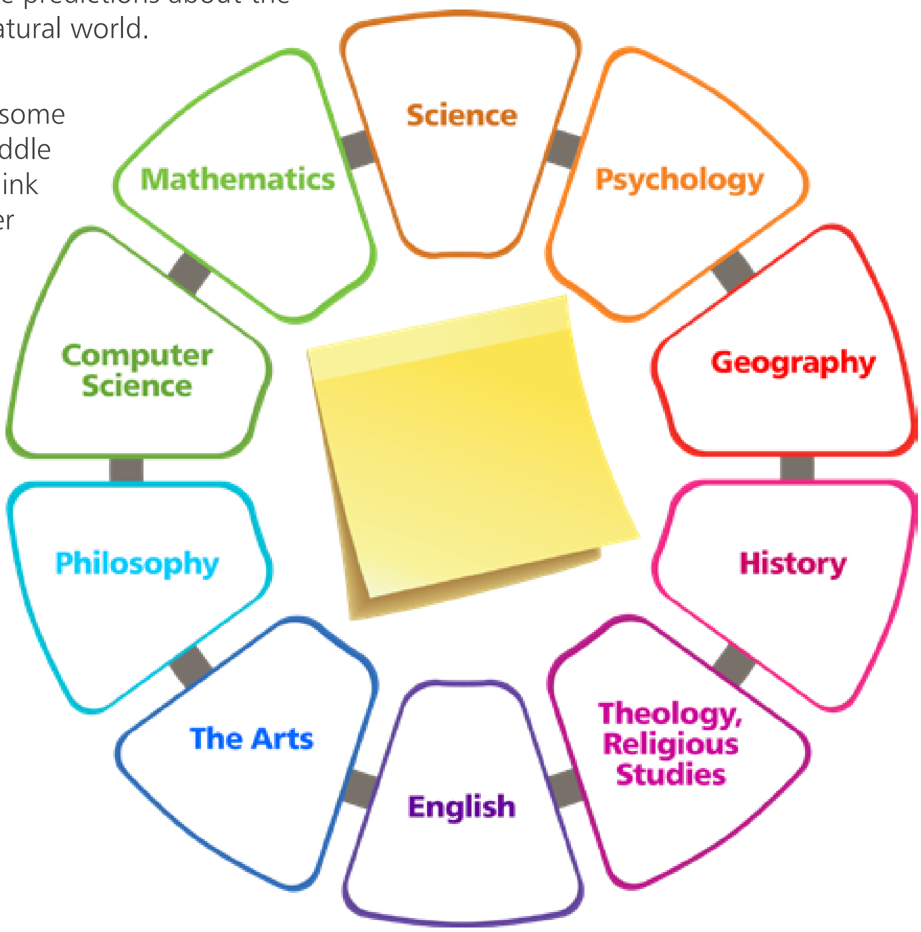
- Science asks **questions** which investigate the nature of the world around us e.g. Earth and Space – the solar system
- Science preferred **methods** include observation, test, predict, seeking patterns, causation, undertaking measurements to test a hypothesis. Seeks repeatability

Science **values** (norms of thought) a consensus in results, that allow us to make accurate predictions about the behaviour of objects in the natural world. These results are objective.

Use the discipline wheel, put some other Big Questions in the middle and encourage students to think about how they would answer these questions.

Example questions include:

- Would it be possible to carry enough water and food in a rocket to keep people alive during such a long journey?
- How would we power spaceships?



Activity 2: What space explorations have occurred over the past 60 years? – Being a Historian!

Space exploration timeline

1957
First satellite in orbit – Sputnik (USSR)

1961
First human in space – Yuri Gagarin (USSR)

1969
First human on the Moon – Apollo 11 (USA)

1976
Viking 1 probe lands on Mars (USA)

1995
First probe on Jupiter – Galileo (USA)

2014
First soft landing on a comet – Rosetta (ESA)

People who study history collect historical evidence from a range of different sources from the past such as newspaper reports, people's stories, objects, and official records. In this activity your child will work as a historian and by looking at the past, think about the big question of 'in the future will people travel and live in space?'. Ask students to:

1. Read the magazine and newspaper extracts. From a historian's viewpoint, what do the extracts have to say about space exploration?
2. Home activity: Students share the extracts with someone in their household to find out what they think about space exploration in their lifetime.
3. Using the timeline above, students select one of the major space exploration events and find at least three historical facts about the event. Students should try to identify their historical sources (where did the information come from), who created the source (e.g. who wrote it). By identifying who created a source, when it was created, a picture can be built up of how accurate the source is and its purpose. If students investigated an object, what is its importance to space exploration. Make students aware that history is open to interpretation. This could be extended into a bigger project about one of the events or a comparison between two of the events.

- https://www.newspapers.com/clip/31632700/neil-armstrong-and-buzz-aldrins-moon/
- https://ysjournal.com/should-more-money-be-spent-on-space-exploration-rather-than-to-solve-humanitarian-problems-on-earth/

Note: Encourage use of key history terms and language. What makes history distinct?

What space explorations have occurred over the past 60 years?

Discuss with others either as a whole class or groups – what they think of the newspapers and what other historical evidence or sources would assist their investigation of space history further. Where could this information come from, who is the source, what is their reason for writing the report, diary entry etc? Were they actually present at the event or is it a secondary source? What do the historical objects or photographs tell us. How do they help future space exploration?

Consider the evidence through the lens of history: the methods used, the language and norms of thought pertaining to history and how evidence is found through analysis of a variety sources which provide facts and narratives about an event or period.

Support your students to identify how

- History asks **questions** about people and events from the past:
- History preferred **methods:** Investigate through examining sources (physical objects or written, audio, video accounts). Select and organise relevant information from a range of sources. Seek an accurate account as far as is possible.

History's **values** (norms of thought) different sources need to be checked for bias and motive. Results allow us to understand what happened in the past and may inform our thinking about events in the present/future. Results are subject to interpretation.

DISCUSSION GUIDE

Travelling and Living Beyond the Earth

This relates to the back of the space card. The following discussion guide provides you with background that you may find helpful. You could read it with students or use it to inform the answers you give and questions you ask in a conversation.

The idea of travelling and living in space no longer applies solely to the realms of science fiction, as governments, scientists and entrepreneurs across the world look for ways to solve the various challenges in our way. For the field of physics, travelling and living in space presents new and exciting challenges.

Physics plays a key role in helping us to work out whether humanity has a future in space, but there are also political, moral and ethical dimensions to be considered. In this workshop, students complete a range of activities to discover ways that physics and other disciplines help to inform our responses to this big question.

COMPARING SCIENCE WITH OTHER DISCIPLINES

When we are thinking like a scientist – we make a scientific model of the solar system in order to answer questions about the distances between our planets. In science we carefully frame questions that we can investigate scientifically. We are looking for evidence that is repeatable, for methods that are reproducible and for answers that are accurate, objective and as far as possible – an answer we can generalise and apply to a lot of situations.

In contrast, in some other disciplines and ways of knowing, such as religion and history we are looking for a bigger picture that includes finding out what people were thinking at the time and what motivated them to behave as they did.

When we think about space travel using the lenses of the humanities, we think about the feelings, values and beliefs of society and people about space inhabitancy. For example, we can use historical sources to talk about what we can learn from previous human exploration of the Earth.

HOW WOULD YOU EXPLAIN A SUNSET?

A day on earth is just over 24 hours long. On some other planets it is shorter and on some planets longer. Once a day – we see a sunrise as our part of the earth moves into sunlight. As our part of the earth moves into darkness – we see the sun apparently set.

You could explain that the earth rotates on its axis each day and as we move into darkness, we see a sunset.

A UNIQUE MOMENT IN TIME

This photograph of a sunset was taken in Toowoomba Australia. If you go with your camera to Toowoomba you too can capture a stunning sunset but it won't be the same sunset because each sunset is unique.

So, a sunset is a unique experience and yet via science we know there will be a sunset every day. And so here is the nature of reality – it is both a string of unique moments in time and yet also a pattern of moments connected by ideas in science.

And in Art, we gaze at a sunset as seen by an artist and it feels both familiar and yet also different to our own experiences. Art can help us to see and experience other people's worlds. Look at this painting of a sunset. It looks like another world, but what we are seeing is our world but at a different time!

This painting is called, "A Landscape at Sunset" by Claude-Joseph Vernet.

CONCLUSION

The big question is – do scientific explanations replace other kinds of explanations? Most scholars say – no – we will always need lots of disciplines and even then, we will never answer all our questions. Science helps us to look for and explain patterns in the natural world. Religion and the wider humanities can help us to look for meaning in the unique moments in our lives.

In conclusion – what do you think about these facts about the Earth?

Almost 70% of our planet's surface is covered by liquid water oceans – that average 4 km deep.

Though we can't feel it, Earth zooms through space in its orbit at an average sped of 30 km per second (or 67,000 miles per hour).

Our planet is an average of 150 million km from the sun. It takes light about eight minutes to get here at light speed!

These are some mind-boggling facts about our Earth – but how do we know? Can we check these facts by investigating scientifically…? Can you turn these facts into good questions for science to investigate?

Working scientifically sometimes prompts us to ask questions that we cannot yet answer. Can you now come up with some new questions that science can investigate – questions where we do not know the answers yet?

Looking at the world and life around us can also prompt Big Questions where we may never have agreed-upon answers. Can you think of some Big Questions where science and other disciplines can inform our thinking – but we may never have a simple agreed-upon answer?

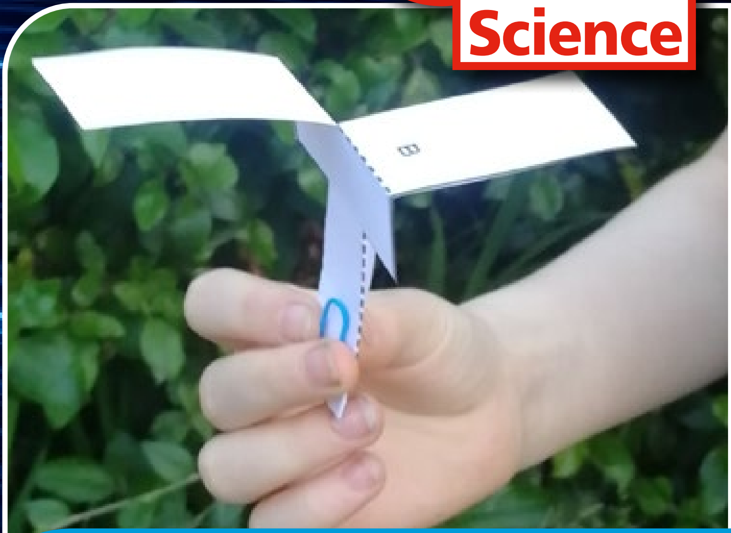
Epistemic Insight

Canterbury Christ Church University

Epistemic Insight

Essential Experiences in Science

Why do spinners spin?



Paper Race

I have two same sized sheets of paper. One is flat and one is scrunched into a ball.

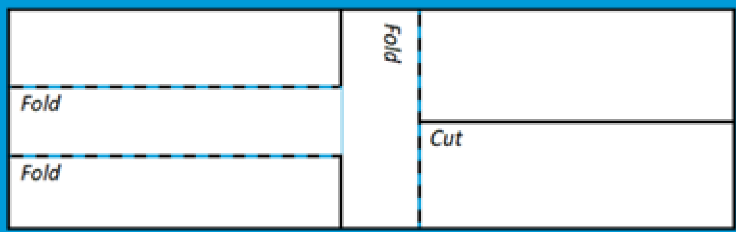
What will happen when I drop them both at the same time from the same height?

Which one will hit the ground first? Do you know why? Try it out!

Observe, Measure, Record

To make a spinner

Copy the template below onto a piece of paper. Fold the dotted lines and cut the solid lines. Fold the two wings in opposite directions. Make 2 spinners.



Challenge 1: Make a spinner that falls quickly. What did you do?

Challenge 2: Make a spinner that falls slowly. What did you do differently?

Challenge 3: Make a spinner that spins quickly. What did you do?

Observe and Record your results.

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Epistemic Insight

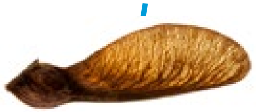
Essential Experiences in Science

Why do spinners spin?

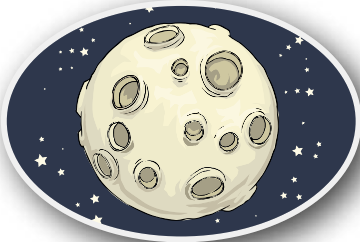
Gravity pulls the spinner downwards.

Think about a parachute. More surface area, means more air resistance. And that means it falls more slowly.

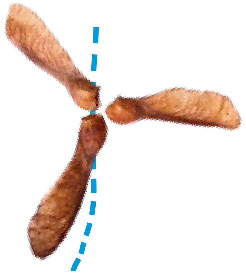
Air resistance is a kind of friction. As the spinner falls, it is slowed down by the air that pushes up on its wing.



Astronauts dropped a hammer and a feather on the moon. Guess what! They hit the ground together! So no air = no air resistance!



On the moon, there's no air.



Sycamore seeds with more wings or wider or longer wings have more surface area – and fall more slowly. Try folding the wings on your spinner.

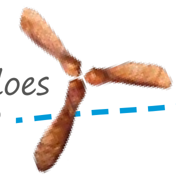
You can also add weights to your spinner, what happens now?

We saw this in the paper race!

Can you make a paper spinner that spins the other way?

The wings of spinners are not symmetrical. Sometimes they are at an angle. Sometimes they are not opposite the centre point. It means the forces are uneven and twist the spinner around.

But why does it spin?



Epistemic Insight

Essential Experiences in Science

How do clouds stay up?

Firstly we need to find out some things about water

Have you seen a spider's web looking like this one?

Or a droplet of water caught in a leaf?

What happens if two droplets run into each other?

Explore, Observe, Record

Dip a straw into a beaker of water and trap some water inside by putting a finger over the end.

Drop water droplets onto a penny. Draw or record your observations.

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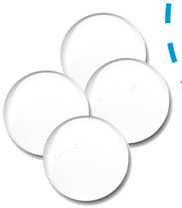
Epistemic Insight

Essential Experiences in Science

Why don't clouds fall out of the sky?

A cloud is made of tiny water droplets.



They are too light to be pulled to the ground.

The droplets of water join up – just as they did on the penny.

The sky darkens...

Big droplets are pulled to the ground by gravity.

What happens to the cloud after it rains?

As it rains, the cloud shrinks.

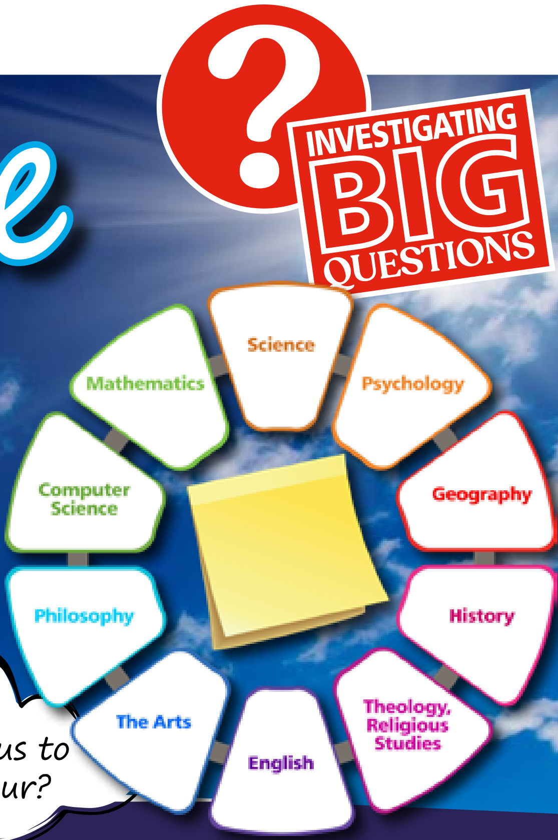
Once the water is gone, there is no more cloud.

You may not see it shrinking because clouds are moving, blown along by the wind.

But you might see a rainbow!

Epistemic Insight

Why is the sky blue?



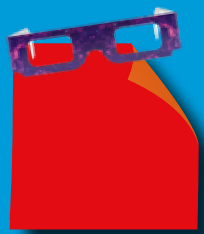
Have you ever wondered why the sky is blue?

Or looked at a bubble and seen colours on its soapy surface?

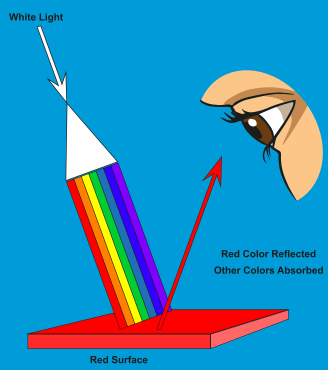
Can science help us to explain colour?

Activity

What do you predict you will observe if you look at a red sheet of paper through the diffraction glasses?



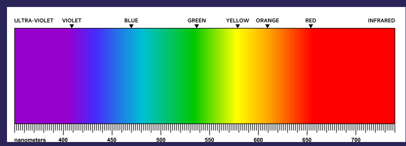
Write down your prediction on your sheet. Now put on the glasses and observe the paper.



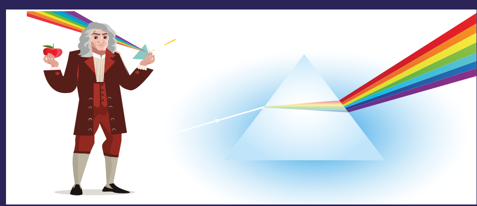
Were your predictions right?

When you look at a red sheet of paper only the red light is reflected to your eye – and you see the paper as red.

Science tells us that everyday light contains all the colours of the rainbow.



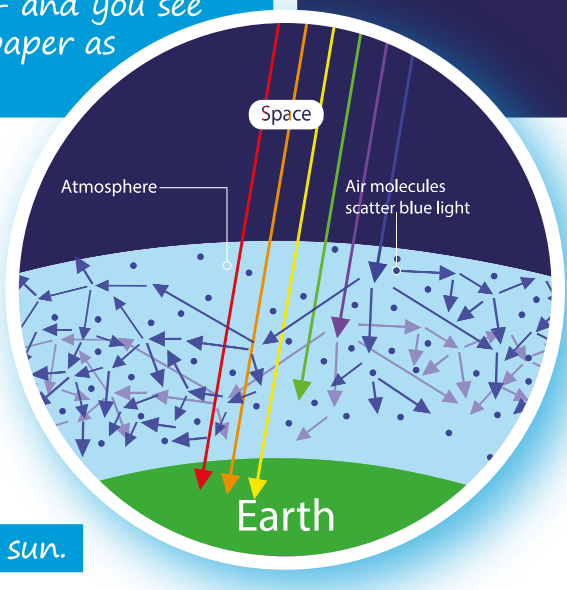
Sir Isaac Newton (a scientist who lived over 300 years ago) discovered he could split up the colours in light using a prism.



When sunlight passes into a bubble, the bubble bends the rays of light and splits the colours.

So why is the sky blue?

Sunlight (containing all the rainbow colours) reaches Earth's atmosphere and is scattered in all directions by the gases and particles in the air.



Blue light is scattered more than the other colours. By the time it reaches your eyes, it seems to have come from all over the sky.

Remember
– never look directly at the sun.

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Epistemic Insight

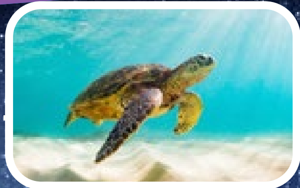
Our Perfect Planet

INVESTIGATING BIG QUESTIONS

Scientists say that the Earth is 'just right for life.

Get ready to find out how perfect we are!

We live in the 'Goldilocks zone' from our star. This is the zone where water is a liquid.



Planets that are closer than we are to the Sun are hotter. Any water boils away.

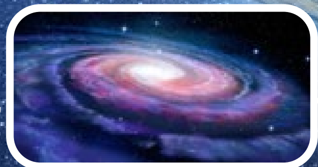
On Neptune the temperature is minus 200 degrees Celsius. Too cold!

Our planet is the only planet in our solar system that is teeming with life.

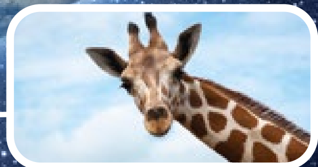
Our planet has been protected from meteor strikes by Jupiter – a giant planet that has a stronger gravitational field than ours.

PERFECT

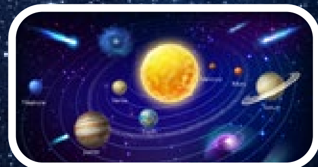
Luckily we are in the space in between two spiral arms.



The spiral arms of our galaxy are risky places to be – because of the risk of stellar collisions.



It means there has been enough time for complex life to evolve on the Earth.



Large stars have short lifetimes but our star, the Sun is the right size for a long stable life.

Epistemic Insight

How do we make sense of the weather?

INVESTIGATING BIG QUESTIONS

Does thunder and lightning scare you or excite you?!

Have you ever leant into a **really strong wind** and felt its force?

Activity

You will need a door that separates a warm room and a colder room. It could be the front door if it's cold outside.

Make a thin strip of tissue.

Open the door a tiny bit.
Hold your tissue down low in the draft of air – which way is the air moving?

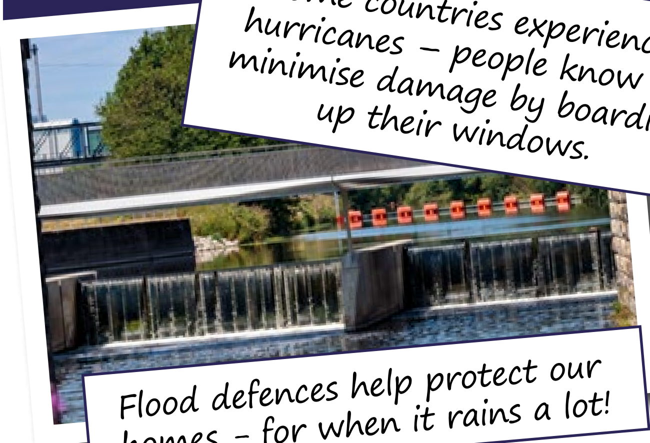
The draft happens because cold dense air is moving into the warmer, thinner air.

We experience the weather directly ourselves.

We can investigate and understand the world around us. We can apply our knowledge to make our lives better and to help others and our natural world.

As we learn more about how the weather works, we can become better at managing its impacts and more insightful about our impact on our world.

Some countries experience hurricanes – people know to minimise damage by boarding up their windows.



Flood defences help protect our homes – for when it rains a lot!

Canterbury Christ Church University

Epistemic Insight

Does God control the weather?

INVESTIGATING BIG QUESTIONS

If there's a God who created everything, then how should we explain bad weather?

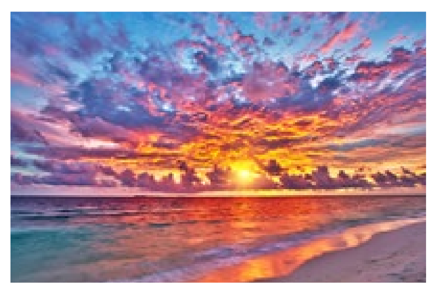
Is a storm a sign that God is angry?

In the Bible it says that Elijah waited for God to speak to him. He saw an earthquake, fire and a strong wind...

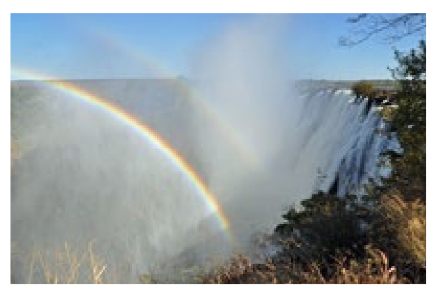
Theologians say that in religious texts, God has chosen many different ways to start conversations with people.

...but when God spoke, it was in a calm, small voice.

In religious texts, where people ask God to explain how he speaks to us, God says, we can't expect to know and understand everything about God.



We ask questions about our weather which we can investigate scientifically.



We know to expect something different everyday.

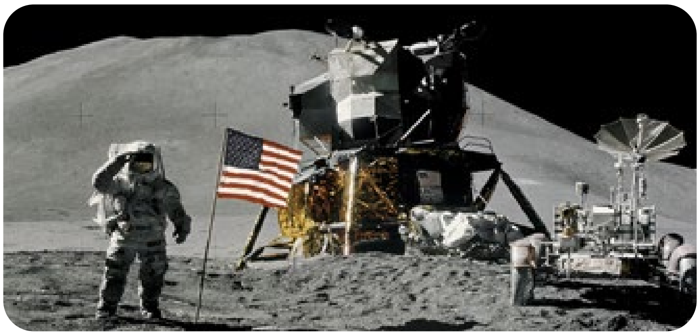
We can apply our knowledge to change our experiences. If you could control the weather – would you? Why or why not? What would you do?

Epistemic Insight

Essential Experiences in Science

In the future will people travel and live in space?

There are lots of science-fiction books and films about space, involving people travelling in space, exploring other planets and meeting aliens. Are these adventures just stories, or could they be possible in the future?



In the past 60 years we have certainly achieved a lot in space exploration. Probes have been sent out into space, and humans have orbited the Earth in space stations and even gone to the moon.

However, the exciting possibility of people travelling large distances and living for longer periods of time in space remains a big question for us all.

Scientific Models

Scientists often use scientific models to help them think about and explain the science they are studying. A simple scientific model is a picture of our solar system as it shows the Sun and the order of the planets.

All scientific models have weaknesses and are not able to explain the science fully. Think about the picture model of the solar system, can you think of some of its weaknesses?

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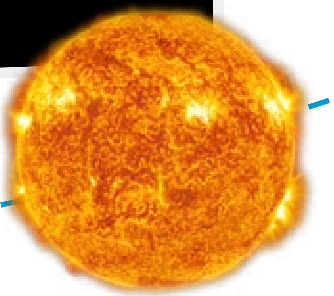
Epistemic Insight

Essential Experiences in Science

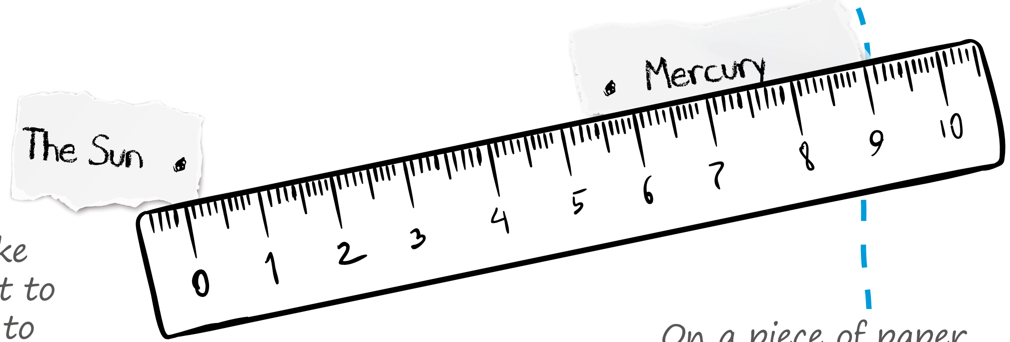
In the future will people travel and live in space?

Let's use a scientific model to help us think about this question.

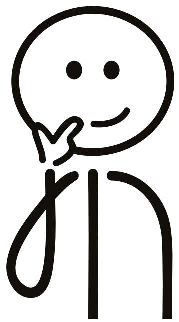


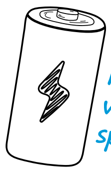
The Sun is the biggest object in our solar system, it is 696, 340 kilometres across, which is 109 times bigger than the Earth.

Imagine if we reduced the Sun down to the size of a full stop, what distance would all of the planets in our solar system be from the Sun and one another?



Would it be possible to carry enough water and food for such a long journey?





How would we power our space ships?

Currently, it would take six months for a rocket to travel from the Earth to Mars, so how long would it take to get to the other planets.

Planets	Actual Distance from Sun (in million km)	Relative Model Distance (in cm)
Mercury	58	5.8cm
Venus	108	10.8cm
Earth	150	15cm
Mars	228	22.8cm
Jupiter	778	77.8cm
Saturn	1420	142cm
Uranus	2870	287cm
Neptune	4480	448cm

On a piece of paper put a full stop and write **The Sun.** On eight other pieces of paper put the names of the planets listed in the table.

Across your floor, use the table to measure the **relative model distance** to each planet from your full stop Sun. Place each planet's label at the measured point.

What do you think? In the future will people travel and live in space?

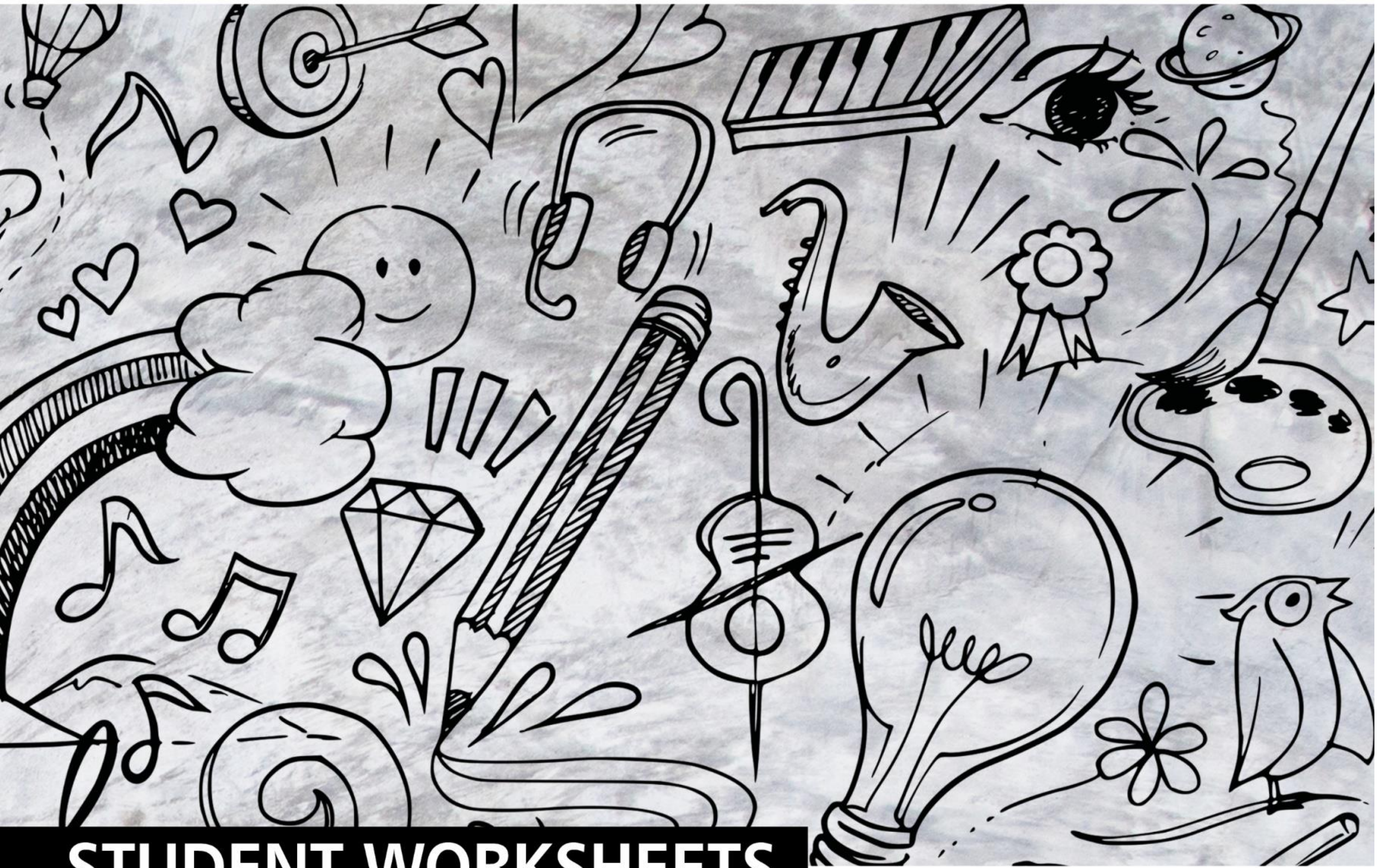
Use your full stop model to help you think about your concerns and ideas about space exploration. Add your ideas to the thought diagram started above.

You could also think about the strengths and weaknesses in the full stop Sun model.

Epistemic Insight

Essential Experiences in Science

Investigating Big Questions



STUDENT WORKSHEETS

APPENDIX

University of Bristol · Centre for Industry Education Collaboration · University of Hull · University of Roehampton London · Canterbury Christ Church University

Contents

Why do spinners spin?

Paper drop exercise.

1. Take 2 sheets of A4 paper (watch out for paper cuts!)

2. Scrunch one into a ball and keep the other one flat.

3. Predict what you will observe when you drop them from the same height.

4. Observe what happens and see if you were right! (Do this a few more times – is the outcome the same?)

4. Record your observations after each drop.

You are about to drop a scrunched up and flat sheet of paper – which will hit the ground first, what's your prediction?

....

....

....

Now try the investigation twice and write down your observations

....

....

....

Try dropping two scrunched up balls, what do you observe now?

....

....

....

What have you found out?

....

....

....

Spinner Activity

Investigation:

1. Can you change how fast a spinner spins?
2. You will need two copies of the spinner template.
3. Cut them out, cutting along the solid lines only (careful with the scissors!)
4. Fold along the dotted lines (section A folds towards you, section B folds away).
5. Explore dropping the spinners and observe them falling and spinning. How many rotations do they do, is the result always the same?)
6. Record your observations in the table on the next page (first box).
7. What happens if you add a paperclip to one spinner (at the bottom, like in the photo!) Will it spin faster/slower/the same/different direction? Predict what you think you'll observe.
8. Now try it out!
9. What happens if you add MORE paperclips?

Investigate	**General observations**	**Comparison – which hit the ground first, did one spin faster?**
Two spinners Dropped from the same height		
Repeat		
Add a paperclip to one of them		
Repeat		
Add more paperclips		

What have you found out?

………

………

………

Challenges

Can you make: i) a spinner that falls slowly, ii) a spinner that falls quickly, iii) a spinner that spins more quickly Did you solve the challenges, if so how?

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How do clouds stay up?

Observing water droplets

1. You will need some water in a container, a straw or pipette, and a penny

2. Predict what you will observe when you place a droplet of water onto the penny – use the pipette or straw for this.

3. Observe what happens and see if you were right! (Do this a few more times – is the outcome the same?)

4. Record your observations at each step.

My prediction: You are about to place a droplet of water onto the penny, record your prediction here? Some key questions to think about are:

- Will the water cover the surface of the penny?
- Will it stay on the penny?
- What shape will the water be?

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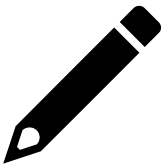
- Draw what you think the penny will look like once you've placed one droplet of water on it.



My observations

Now try the investigation and write down your observations

....

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....

Is it what you were expecting?

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....

What have you found out?

....

....

....

Now predict what will happen if you place another water droplet close to the first one on the penny. Record your prediction here?

....

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....

My prediction: Draw what you think the penny will look like once you've placed another droplet of water on it?

My observations

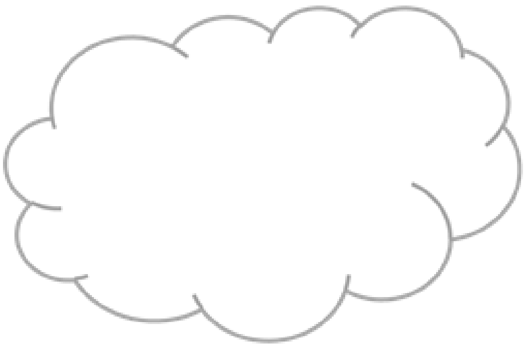
Now try the investigation and write down your observations

What do you notice?

How many drops of water are on the penny now?

Challenge: Predict how may water droplets you can you fit onto the penny.

Write your prediction in the cloud. Then test it out!

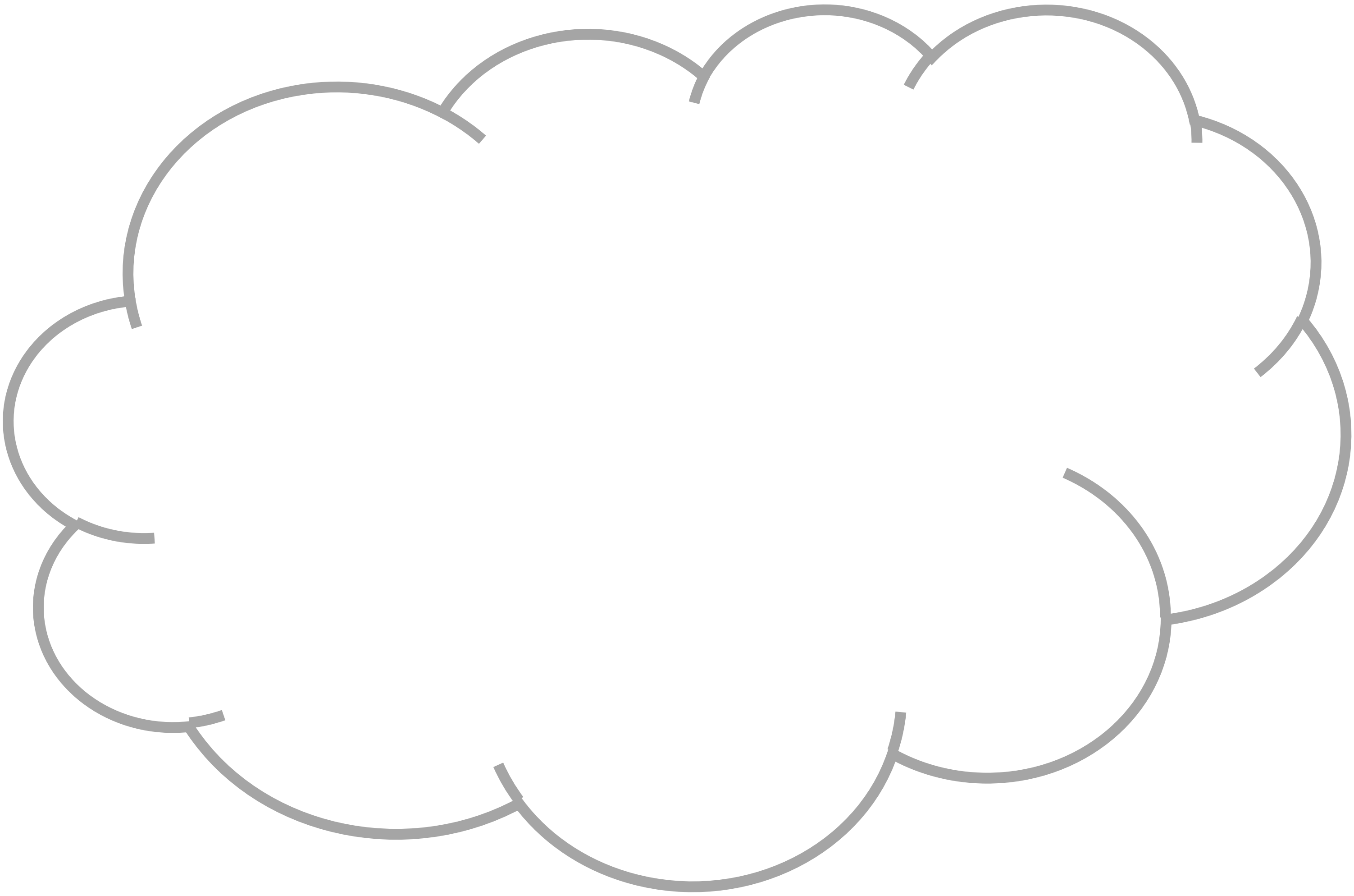


What did you observe?

Were you correct? Write your observations here.

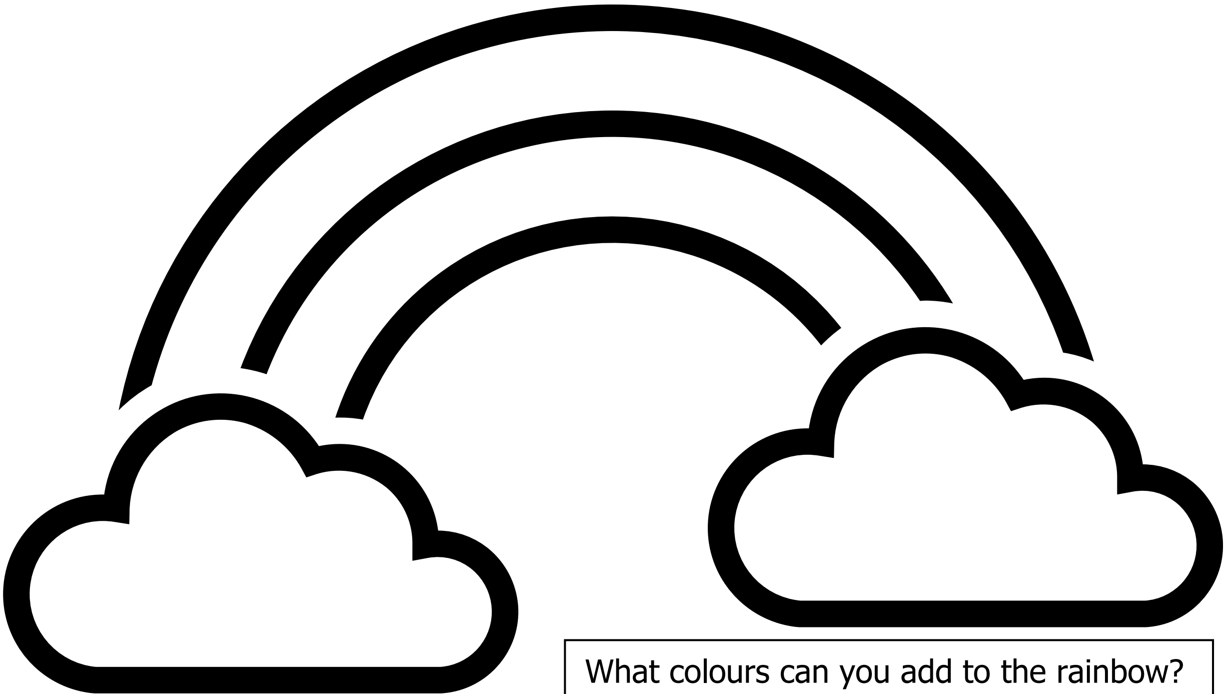
Write what you know about clouds below. Here are some questions to consider:

- What are they made of?
- What is the effect of gravity on clouds?
- What is the effect of gravity on raindrops?
- What changes must happen to the water in the clouds?



Why is the sky blue?

- **What are rainbows made of?**
- **Where do the colours come from?**
- **Are the colours there when we can't see them?**



What colours can you add to the rainbow?

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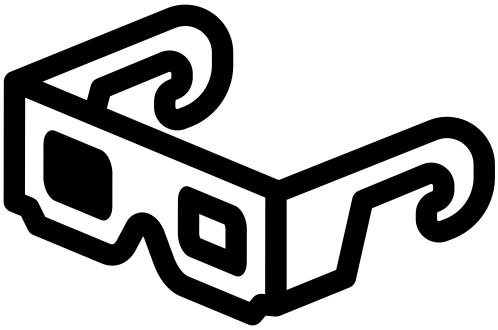

You are about to use the diffraction glasses – what do you think you will see when you look at red paper through the glasses? What's your prediction?

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Now put on the glasses and look at the red paper, write down your observations

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What do you think you will see when you look at purple paper through the glasses? What's your prediction?

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Now put on the glasses and look at the purple paper, write down your observations

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What about if you look at white paper or black paper through the glasses? What do you predict?

White paper

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Black paper

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What did you observe? What have you found out?

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Epistemic Insight

How do we make sense of the weather?

How does the weather make me feel and affect what I do?

Compare two or more types of weather in the table below. Either draw a picture or write how the weather make you feel and affects what you do.

	Thunder and lightning	Hot sunny weather	Severely windy weather	Snow and ice	Heavy rainfall and flooding
How does the weather make me feel?					
Are there any dangers?					
How can I protect myself?					

Windsock activity

Please write down your observations of the windsock at three different times during the day, such as morning midday and afternoon.

Observations of my windsock:

	Time of observation	**Draw a picture of what your windsock looks like!**	**Words to describe what the windsock looks like**	**What does this tell us about the strength and direction of the wind?**
1.				
2.				
3.				

Living and traveling in space

How big is Space – Being a scientist!

Imagine if we reduced the Sun to the size of a full stop, what distance would all of the planets in our solar system be from the Sun and one another?

You will need a piece of paper, a ruler and a pen or pencil. Tear your piece of A4 paper into 9 pieces.

1. On one of the pieces put a Full Stop and write The Sun. On the other pieces copy the names of the planets listed in the table below.

2. Across your floor, use the information in the table to measure the relative model distance to each planet from your full stop Sun. Place each planet's label at the measured point.

Planets	Actual Distance from Sun (in million km)	Relative Model Distance (in cm)
Mercury	58	5.8 cm
Venus	108	10.8 cm
Earth	150	15 cm
Mars	228	22.8 cm
Jupiter	778	77.8 cm
Saturn	1420	142 cm
Uranus	2870	287 cm
Neptune	4480	448 cm

Challenge: Thinking about the model:

Currently, it would take six months for a rocket to travel from the Earth to Mars. Using your Full Stop model of the solar system to help your thinking,

In the future will people travel and live in space? How has the solar system model helped to answer the big question?

Think about how long it would take for a rocket to travel to more distant planets, and what might be the challenges?

How many issues and ideas can you think of?

I have been thinking like a scientist!

Record your science thoughts and observations here!

Record your findings, thoughts, drawings, images from your science investigations here…

In the future will people travel and live in space?
How can the history sources and investigating the past help answer the big question?

I have been thinking like a historian!

Record your sources from the past? Who wrote them? Why? What do the sources tell you about space exploration?

Record your findings, thoughts, drawings, images from your history investigations here...

Essential Experiences in Science | Epistemic Insight | Investigating Big Questions

Investigating Big Questions CPD

CPD Overview

Aims

The *Investigating Big Questions* (IBQ) project aims to facilitate and support science in school and at home during the recovery phrase of the Covid-19 pandemic. One aim is to energise and support teachers with ways to provide practical 'hands-on' science and another is to engage students (particularly disadvantaged students) with the excitement of 'thinking like a scientist'.

Science and technology prompt us to ask Big Questions and raise some mind-boggling possibilities. Children's interest in science can be engaged by considering these questions and possibilities, especially in the primary school classroom where children's imaginations are easily fired up by ideas like 'Can robots think for themselves?', 'Do we want to have driverless cars?', 'Why does the earth exist?', 'When, if at all, will humans live and work on other planets?', and 'Will we one day control the weather?'

If, as teachers and educators, we want or find ourselves engaging with these Big Questions and possibilities, we can turn them into a learning opportunity by clarifying with children what kinds of questions do we address IN science, and how does science interact with the kinds of questions we ask and explore in other disciplines?

The five investigation cards in the research provide a learning journey for children to follow. Teachers should include at least three activities and we hope many will want to include all five. One 'good' option for the research would be three in the classroom and two others at home or four in the classroom and one activity at home.

Each session plan has an activity, teaching notes, and a discussion guide. They make sense best when taken together – so if something goes home, it should be a full suite of the activity, including teaching notes and discussion guide – or it could be a consolidation activity where children repeat an investigation and explore the ideas with a parent. The same goes for the classroom – you should use each activity to teach the ideas in the notes and explore the ideas in the discussion – rather than splitting up the activity, the teaching, and the discussion.

The Bag

The bag of resources, the 'Discovery Bag', contains something for each investigation. It is up to the researcher and the class teacher if children have everything at once or if the items build over the unit. Participating classrooms each have a full set of bags and all the equipment in the resource for the children.

The Research

We have three research aims running concurrently. Each collaborating university has eight classrooms taking part. The main research aim is to look at the impacts of the intervention on those eight classrooms (children and teachers).

In parallel we are staging the research so that we can compare the learning that happens in one classroom during the 'unit of work' with the learning in another classroom where they are not doing the unit. By the end of the project all eight classrooms have worked on the activities.

Thirdly, we are making comparisons and measurements with sub-groups – such as impact on classrooms with high proportions of disadvantaged students versus classrooms with lower proportions of disadvantaged students. For the surveys, information on disadvantage can come from teachers – not directly from the children. For interviews, researchers should develop appropriate tools to address this (or not) with children.

Ethics and GDPR are detailed on our website (https://www.epistemicinsight.com). For GDPR, the surveys operate under 'legitimate interest' and not 'consent'. This means information about the survey is provided to parents and carers. Parents/carers have the option to 'opt out'. If they do nothing, then some data from their child's survey goes into the study. No children's names or personal identifiers are used in the research. None of the questions in the survey 'force' the child to respond so the child can also 'opt out' at each question.

If a teacher says a child is opting out – they should READ the survey and not submit any responses. The survey is a part of the learning journey – it helps children to recognise the teaching when it comes.

Conditions for the survey: Most important is children feel happy about what they are doing. The teacher can talk, encourage, and help. Children should be told not to share ideas but do it 'with a smile' e.g. "Don't give away your answers to your neighbours – you put in your own ideas and we can all talk later."

If children meet a word they don't understand, they should tick 'I don't understand the question'. Part of the research is to show that children don't know some key words for talking about knowledge – until we teach them via the intervention. Teachers can explain to children that by ticking they don't understand - this is how the teacher will know what to explain later.

Suggested Intervention activity schedule

The Pre-survey should be issued to students and teachers before any engagement with the research resources.

Classroom 1	Classroom 2
Pre-survey	Pre-survey
Activity 1	
Survey after activity 1	
Other activities	
Post-unit survey	Pre-unit survey
	Activity 1
	Survey after activity 1
	Other activities
Final post-intervention survey	Final post-intervention survey

More about the content

The five cards focus on enquiry skills and epistemic insight rather than subject content. Epistemic insight means 'knowledge about knowledge'. For example, one of the key aims of the 'spinner activity' is to build children's understanding that science is a discipline that asks and investigates questions about the natural world.

Across the five activities, students should become more confident in:

- Explaining what makes science distinctive as a discipline
- Explaining with examples that science and other disciplines can inform our thinking about Big Questions. Appreciating that Big Questions frequently do not have simple agreed-upon answers.

The focus for Big Questions is on questions that bridge science, religion, and the wider humanities. These questions can be hard to talk about because there are no easy answers and there seem to be many competing and sometimes contradictory approaches and responses. At the same time, many children, including many of those we want to reach, are engaged by Big Questions and mind-boggling possibilities. Big Questions include 'Can robots think for themselves?' 'Do we want to have driverless cars?', 'Why does the earth exist?', 'When if at all will humans live and work on other planets?', and 'Will we one day control the weather?'

CPD helps teachers to create an appropriate suite of activities, Big Questions, and teaching points to make. The guides and resources move step by step through the key ideas, explaining 'working scientifically' and then how 'working scientifically' interacts with Big Questions. Language plays a key role, and another aim is for children and teachers to become familiar with key words and why they are useful.

These established tools and methods will be used within this research to discover best practice and to test the efficacy of interventions that are designed to raise epistemic insight on children's enquiry skills, scientific literacy, science capital, academic self-concept, and attitudes to learning.

The table below lists some of the statements from the children's surveys, how these link with KS2 and KS3 learning and student insight, and on what cards these learning and insight points can be found. Not all the survey statements link specifically to an Epistemic Insight learning and several of the questions share an insight.

For those working with primary, here is a useful section from the National Curriculum for Science for Year 5-6:

Year 5-6

https://www.gov.uk/government/publications/national-curriculum-in-england-science-programmes-of-study/national-curriculum-in-england-science-programmes-of-study

Notes and guidance (non-statutory)

Pupils in years 5 and 6 should use their science experiences to: explore ideas and raise different kinds of questions; select and plan the most appropriate type of scientific enquiry to use to answer scientific questions; recognise when and how to set up comparative and fair tests and explain which variables need to be controlled and why. They should use and develop keys and other information records to identify, classify and describe living things and materials, and identify patterns that might be found in the natural environment.

They should make their own decisions about what observations to make, what measurements to use and how long to make them for, and whether to repeat them; choose the most appropriate equipment to make measurements and explain how to use it accurately. They should decide how to record data from a choice of familiar approaches; look for different causal relationships in their data and identify evidence that refutes or supports their ideas. They should use their results to identify when further tests and observations might be needed; recognise which secondary sources will be most useful to research their ideas and begin to separate opinion from fact.

[there's an assumption we could make that 'sort opinion from fact' means we reject opinion - however a more nuanced take on this is that - we have established some scientific 'facts' and these will inform our opinion about Bigger Questions.]

They should use relevant scientific language and illustrations to discuss, communicate and justify their scientific ideas and should talk about how scientific ideas have developed over time.

Statement	Key stage 2 EI learning	Key Stage 3 EI learning	Student Insight KS2	Student Insight KS3	Card(s)

I have heard of the term 'discipline'	Ways of knowing At school we learn to think like scholars	Ways of knowing A school is a multidisciplinary arena	Become familiar with the notion of discipline(s); EI vocabulary	Familiarisation of the distinctiveness of different disciplines	All
At school I have learnt what a discipline is	Ways of knowing At school we learn to think like scholars	Ways of knowing A school is a multidisciplinary arena	Become familiar with the notion of discipline(s); EI vocabulary	Different disciplines investigate a question differently	All
At school I have learnt that science is an example of a discipline	Ways of knowing Science has some similarities and some differences with other ways of knowing that we learn about in school	Ways of knowing Different disciplines have different preferred questions, methods and norms of thought	Recognising the distinctiveness of science which investigates through experiments using observation compared with other ways of knowing	Demonstrate the distinctiveness of science through its preferred questions, methods and norms of thought	Why do spinners spin? How do clouds stay up?
I know what makes science different to history as a discipline	Ways of knowing Science has some similarities and some differences with other ways of knowing that we learn in school	Ways of knowing Different disciplines have preferred questions, methods and norms of thought	Science investigates the natural world through direct observation whereas history investigates a range of sources from the past	Science investigates the natural world through objective and verifiable experiments using observations whereas history examines	Why do spinners spin? How do clouds stay up? In the future will people travel and live in space?'

				different sources from the past and checks for bias and motive	
Statement	Key stage 2 EI learning	Key Stage 3 EI learning	Student Insight KS2	Student Insight KS3	Card(s)
At school I have learnt what kinds of questions different disciplines answer	Ways of knowing Science has some similarities and some differences with other ways of knowing that we learn about in school	Ways of knowing Scholars ask and explore big and small questions. Different disciplines have different preferred questions, methods and norms of thought	Highlight the similarities and differences of disciplines through their preferred questions, methods and norms of thought	Compare how different disciplines apply contrasting methods and norms of thought to a question	In the future will people travel and live in space?'
At school I have learnt what makes a question a good question for science	Nature of science in Real world and multidisciplin ary arenas Science begins with observations of the natural world and constructing ways to explain our	Nature of science in Real world and multidisciplin ary arenas Some questions are more amenable to science than others	Direct observation is key to investigating scientifically	Science investigates the natural world through objective and verifiable experiments using observations	Why do spinners spin? How do clouds stay up?

	observations . Some methods are more scientific than others.				
I can explain how different disciplines investigate (explore) the same question	Ways of knowing A cross-disciplinary question is framed to be investigated in two disciplines	Ways of knowing A multidisciplinary question can be interpreted through the lenses of three or more disciplines	Highlight the similarities and differences of how two different disciplines interpret and investigate a question	Demonstrate how different disciplines interpret and investigate a question	In the future will people travel and live in space?’
All of our questions can be answered by science	Relationships between science and religion Awe and wonder prompt us to ask questions about the world around us – including big questions	Relationships between science and religion There are some questions that science hasn’t yet and may never be able to answer	Science asks smaller questions whereas Big questions are informed by science and other disciplines	Big questions provoke a multidisciplinary response and are not answered by science alone	How do we make sense of the weather? Why is the sky blue?
Statement	Key stage 2 EI learning	Key Stage 3 EI learning	Student Insight KS2	Student Insight KS3	Card(s)

I like to think about Big Questions like whether a robot can be like a person	Relationships between science and religion Awe and wonder prompt us to ask questions about ourselves and the world around us – including big questions	Relationships between science and religion Today we ask big questions about human personhood and the nature of reality that bridge science and religion	Discussion of different 'why' questions and how different disciplines could respond	Develop discussion of Big questions by investigating through science and other disciplines.	In the future will people travel and live in space? Why is the sky blue? How do we make sense of the weather?
I talk at home about Big Questions like whether a robot can be like a person	Relationships between science and religion Science and religion are mostly concerned with different types of questions, including different types of why question.	Relationships between science and religion Today we ask big questions about human personhood and the nature of reality that bridge science and religion	Awe and wonder prompt us to ask questions about ourselves and the world around us – including big questions	Develop discussion of big questions by investigating through science and other disciplines.	In the future will people travel and live in space?' Why is the sky blue? How do we make sense of the weather?
I talk at home about what we learn at school					
Science and religion work	Relationships between	Relationships between	Recognise that science and religion	Science and religion respond to a	Why is the sky blue?

together like friends	science and religion Science and religion are mostly concerned with different types of questions, including different types of why question	science and religion Some people say that science and religion are compatible, and some people say they are not	can both have something to say	question in different contrasting ways – both are valid	How do we make sense of the weather?
Science makes it hard to believe in God (or a Greater Being)	Relationships between science and religion Science and religion are mostly concerned with different types of questions, including different types of why question.	Relationships between science and religion Some people say that science and religion are compatible, and some people say they are not	Recognise that science and religion can both have something to say	Science and religion can respond to a question in different contrasting ways – both are valid	Why is the sky blue? How do we make sense of the weather?
Statement	Key stage 2 EI learning	Key Stage 3 EI learning	Student Insight KS2	Student Insight KS3	Card(s)
Science and religion disagree on so many things they can't both be true	Relationships between science and religion Science and religion are mostly	Relationships between science and religion Some people say that science and	Recognise that science and religion can both have something to say	Science and religion can respond to a question in different contrasting	Why is the sky blue? How do we make sense of the weather?

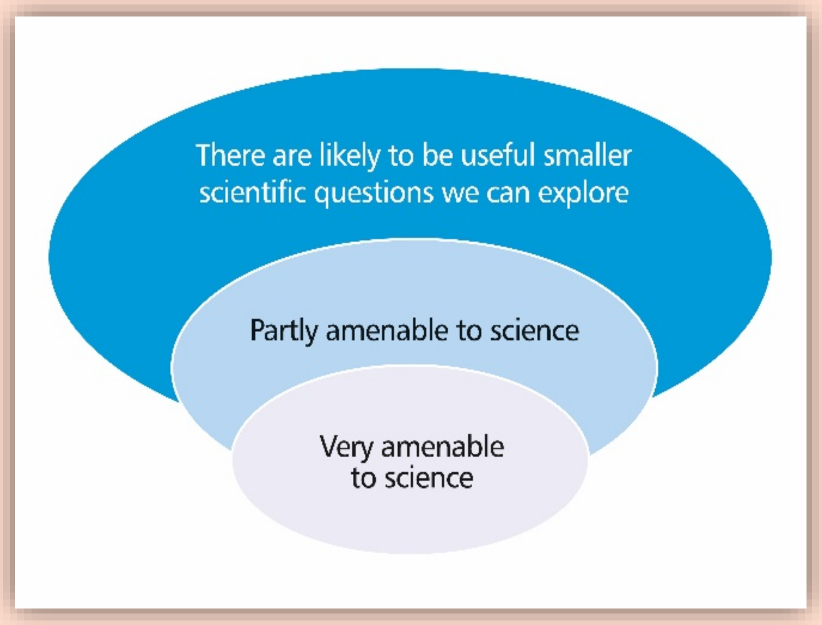
	concerned with different types of questions, including different types of why question	religion are compatible, and some people say they are not		ways – both are valid	
I enjoy science					
I enjoy talking about science.					
When I grow up, I would like a career in science					
I can give an example of how science helps us to think about Big Questions	Relationships between science and religion Today we ask questions about human personhood and the nature of reality that bridge science and religion.	The nature of science in real world contexts and multidisciplinary arenas Today we ask questions about human personhood and the nature of reality that bridge science and religion.	Recognise that science and religion can both have something to say	Develop discussion of big questions by investigating through science and other disciplines.	All
I like finding out how to	Ways of knowing and	Ways of knowing and	Highlight the similarities	Demonstrate how	All

use disciplines to answer Big Questions	how they interact Science has some similarities and some differences with other ways of knowing that we learn about in school.	how they interact Different disciplines have different preferred questions, methods and norms of thought.	and differences of how two different disciplines interpret and investigate a question	different disciplines interpret and investigate a question	
Science helps me explore questions that interest me	The nature of science in real world contexts and multidisciplinary arenas Science begins with observations of the natural world and constructing ways to explain our observations.	The nature of science in real world contexts and multidisciplinary arenas Some questions are more amenable to science than others	Recognising the distinctiveness of science which investigates through experiments using observation compared with other ways of knowing	Demonstrate how different disciplines interpret and investigate a question	All
Learning science increases my sense of wonder about our	The nature of science in real world contexts and multidisciplinary arenas	The nature of science in real world contexts and multidisciplinary arenas	Recognising the distinctiveness of science which investigates through	Science investigates the natural world through objective and	All

amazing world	Science begins with observations of the natural world and constructing ways to explain our observations	Science informs our thinking about every aspect of our lives	experiments using observation compared with other ways of knowing	verifiable experiments using observations	
What makes a question a good one to investigate using science?	Nature of science in Real world and multidisciplinary arenas Science begins with observations of the natural world and constructing ways to explain our observations	Relationships between science and religion Science informs our thinking about every aspect of our lives. A good method in science seeks accuracy, objectivity, precision, repeatability, reproducibility, and adherence to good conduct	Science investigates the natural world through direct observation	Science investigates the natural world through objective and verifiable experiments using observations	All

VOCABULARY	DEFINITION
Big Questions	A question that is intended to open-up big areas of thought and will need more than one discipline to inform how we answer (we may never arrive at a definite answer). Big Questions about human personhood and the nature of reality are questions that bridge science, religion, and the wider humanities. For example: 'Can robots think for themselves?', 'Do we want to have driverless cars?', 'Why does the earth exist?', 'When if at all will humans live and work on other planets?', and 'Will we one day control the weather?'
Disciplines	A branch or field of knowledge that is studied. In EI – you will need to help children to become familiar with the word 'discipline'. You could give them examples from their timetable: Science, history, geography, mathematics.
Subjects	A school subject may focus on working with one discipline or it may cover more than one.
Multidisciplinary questions	Questions that require more than one disciplinary approach to inform: Which disciplines could inform an answer to the question, "Why do we wear shoes?"
Big questions and small questions	Big questions call for responses that draw on multiple disciplines, whereas a small question is one that has been framed to be answered within a discipline. The answer to a small scientific question, such as "How do sounds travel?" can inform our thinking about a big question, such as "Why do we love music?"

Bridging question	A question that is pedagogically engineered (designed by the teacher) to bridge two disciplines. An example is "Why did the Titanic sink?" which bridges science and history so that students can compare and contrast how each discipline interprets the question, investigates the question, arrives at an answer and evaluates the answer to see if it is a good answer.
Discipline Wheel	An epistemological tool, which asks a big question and encourages students to choose from a range of disciplines to investigate the question. We can also put a Bridging Question into the centre – to give children practise with identifying which disciplines to work with. 
Epistemic Insight	Knowledge about knowledge, particularly knowledge about disciplines and how they interact.
Observation	Science begins with observations of the natural world and constructing ways to explain our observations.

A question that is amenable to science	These are questions that can be answered using scientific methods. "What is life?" is more amenable to science than the question, "What is the meaning of life?"
Bubble tool	An epistemological tool, which considers the level of amenability a question has to science. 
Epistemic Insight Curriculum Framework	Statements about the nature of scholarship and knowledge that reflect the aims of the national curriculum.
Disciplinary / Epistemic knowledge	Knowledge about disciplines and the questions, methods, and norms of thought specific to them. Developing an appreciation of the strengths and limitations of individual disciplines.
Scholar	A person who pursues a field of study to develop expert knowledge.

Think like a scholar	Explain how different disciplines investigate a question. Illustrate how another discipline (like history) is different to science.
Strengths and limitations of a discipline	How effective a disciplines method and norms of thought are in responding to a question?
Questions, methods & norms of thought	An example through the lens of Science... Questions An amenable question for Science: 'Does the size of a parachute affect how quickly an object falls to earth?' (We can come up with an idea about how the natural world works and make predictions and decide what can be measured, observed, and repeated.) Methods Science involves generating and testing ideas about natural phenomena and objects by gathering repeatable objective observations. Norms of thought Scientific knowledge – a good answer in science helps us to understand how the natural world works and is supported by repeatable observations and measurements.