Can We Get Humans to Mars?

Teacher Handbook

THE SCHOOLS' OBSERVATORY

FUNDED BY A PARTNERSHIP GRANT FROM THE ROYAL SOCIETY

PROUD TO BE PART OF LIVERPOOL JOHN MOORES UNIVERSITY

Can We Get Humans to Mars?

Welcome

This free programme (funded by Liverpool John Moores University and the Royal Society) is designed to spark curiosity, build scientific skills, and give students a taste of real-world space exploration — all while supporting the Earth and Space topic in the national curriculum.

The overall Mars project consists of 6 mini-investigations. 4 of these will be delivered by STEM professionals, with the other 2 being teacher-led.

Information for each teacher led investigation can be found in the relevant sections of this Handbook.

Appendix 1 contains tables for writing information about student accounts (on The Schools' Observatory's website), which are needed for Investigation 1

Extension activities for the STEM professional led investigations are included Appendix 2.

Information about the specific skills students will develop, and how the project links with Gatsby Benchmarks, is also included in the appendices.

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What Do Humans Need to Survive?

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Learning Objectives

- To identify the basic resources for human survival on Earth and in space
- To reflect on Earth's sustainability and protecting our planet
- To design a Moon Base with essential life systems

Career Link: Engineer/Architect

Curriculum Links

Subject	Topic	Year	Topic Elements
Science	Working Scientifically	Lower Key Stage 2	Using straightforward scientific evidence to answer questions or to support their findings
		Upper Key Stage 2	Identifying scientific evidence that has been used to support or refute ideas or arguments
	Animals, including humans	Year 3	Identify that animals, including humans, need the right types and amount of nutrition, and that they cannot make their own food; they get nutrition from what they eat
		Year 6	Recognise the impact of diet, exercise, drugs and lifestyle on the way their bodies function
	Living things and their habitats	Year 4	Recognise that environments can change and that this can sometimes pose dangers to living things
	Electricity		Identify common appliances that run on electricity
	Forces	Year 5	Explain that unsupported objects fall towards the Earth because of the force of gravity acting between the Earth and the falling object
Mathematics	Statistics	Year 5	Complete, read and interpret information in tables, including timetables

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Subject	Topic	Year	Topic Elements
English	Writing – composition	Years 3 and 4	Plan their writing by discussing and recording ideas
	Writing – vocabulary, grammar and punctuation		Develop their understanding of the concepts set out in English Appendix 2 by extending the range of sentences with more than one clause by using a wider range of conjunctions, including when, if, because, although
	Reading – comprehension	Years 5 and 6	Retrieve, record and present information from non-fiction
			Provide reasoned justifications for their views
Design and Technology	Design	Key Stage 2	Use research and develop design criteria to inform the design of innovative, functional, appealing products that are fit for purpose, aimed at particular individuals or groups
			Generate, develop, model and communicate their ideas through discussion, annotated sketches, cross-sectional and exploded diagrams, prototypes, pattern pieces and computer-aided design
	Evaluate		Evaluate their ideas and products against their own design criteria and consider the views of others to improve their work
	Cooking and nutrition		Understand and apply the principles of a healthy and varied diet
Geography	Human and physical geography	Key Stage 2	Describe and understand key aspects of Human geography, including: types of settlement and land use, economic activity including trade links, and the distribution of natural resources including energy, food, minerals and water

Lesson Plan

Possible Student Misconceptions:

- Only the Earth has gravity
- Gravity only acts on the planet's surface
- Plants breathe like humans

Materials:

- Lesson PowerPoint presentation
- Student Workbooks
- Pencils, coloured pencils, felt-tips, etc.
- Optional: Teacher Handbook (see referenced pages for more information/guidance about the activity)

Duration	Activity	Pages	Materials
2 minutes	Recap what happened in the last investigation and how it links to the current investigation and overall Mars project.	Teacher Handbook: 8	Lesson PowerPoint presentation Student Workbooks
8 minutes	Students reflect on the question 'If we wanted to live elsewhere in space, what would we need to survive?'. Students complete the 'Resources for Survival' activity in their workbooks. Discuss answers as a class before students mark their work.	Teacher Handbook: 9 – 12 Student Workbook: 12	Lesson PowerPoint presentation Student Workbooks
5 minutes	Students reflect on the question 'What other resources would make astronauts feel happy, comfortable, and less homesick?'. Students complete the 'Essential or Extra' activity in their workbooks. Show answers to class and students mark their work.	Teacher Handbook: 12 – 14 Student Workbook: 12	Lesson PowerPoint presentation Student Workbooks
10 minutes	Show students the comparison table for Earth, Moon, and Mars. They use this to complete the 'Comparing the Earth, Moon, and Mars' activity in their workbooks. Show answers to class and students mark their work.	Teacher Handbook: 15 – 17 Student Workbook: 13	Lesson PowerPoint presentation Student Workbooks

What Do Humans Need to Survive?

Duration	Activity	Pages	Materials
10 minutes	Explain to students the unique features of our planet. Show students the pictures of human activities that are damaging the planet and ask them 'What's gone wrong?'. Select some students to share their ideas and discuss as a class. Show students the pictures of sustainable activities and ask them 'How can we live more sustainably?'. Students write their ideas in their workbooks to complete the 'Sustainable Earth' activity. Discuss answers as a class before students mark their work.	Teacher Handbook: 18 – 23 Student Workbook: 14	Lesson PowerPoint presentation Student Workbooks
20 minutes	Show students the video about water recycling on the ISS. Students then complete the Basecamp Design activity in their workbooks, drawing the items they will include and adding any necessary labels to help show their ideas.	Teacher Handbook: 24 – 27 Student Workbook: 14 – 17	Lesson PowerPoint presentation Student Workbooks Pencils, coloured pencils, felt-tips, etc.
5 minutes	Students reflect on the design on their Moon Bases by completing the questions in their workbooks: 'What is your favourite thing about your Moon Base?' and 'How will this help you to live healthily and happily in space?'.	Teacher Handbook: 27 Student Workbook: 18	Lesson PowerPoint presentation Student Workbooks

How does it link to the Mars project?

Previously, students were introduced to the Mars project and the 6 investigations. Each will progress them towards the goal of launching to Mars and carrying out their missions on the planet.

Investigation 1 involved students studying the Moon's surface, identifying different observable features, and then choosing a location for their Moon Base and requesting an observation of this area.

In this investigation, students will act as engineers/architects and explore how to establish a liveable Moon Base. This could act as a launch site towards Mars. Yet, more importantly, we can model building and living in a base much closer to Earth.

This is beneficial because:

- Moon-Earth communication is quicker than Mars-Earth
- Resupplies would arrive in around 3 days
- People can easily be evacuated to Earth if anything goes wrong

By testing equipment and techniques in a safer location (the Moon), the base can be improved before it is built much further away on Mars.

Investigation Overview

Students will think about the resources on Earth that are important for survival, how these are obtained, and the impact this has on the sustainability of our planet.

They will also compare environmental features of the Earth, Moon, and Mars – not only to shape the design of their Moon Base, but to reflect on the importance of living sustainably as well.

Using the template Moon Base design and provided prompts, students will draw and label the different items within their base and explain how these can help them to survive.

Further information and guidance is provided in the specific sections for each activity.

Activity: Resources for Survival

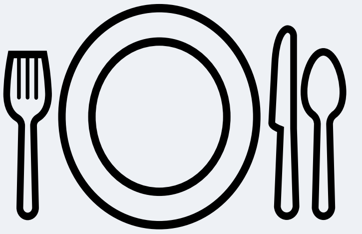
Ask students 'If we wanted to live elsewhere in space, what would we need to survive?'. You may wish to lead a class discussion or have students talk in pairs/group to generate ideas.

Students write these resources in their workbooks. As an extension task, they tick the resources that are easier to get on Earth vs the Moon or Mars.

The main resources that we've identified are food, water, oxygen, shelter, and electricity/power. Other resources that students may have mentioned could be more relevant to the next activity.

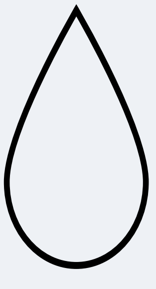
Food

Pupils may give this answer or use specific examples of food instead (e.g. cereal). If an example is used, ask them if it would be healthy to eat only that food all the time.



This should highlight that different foods give us different nutrition, and that a healthy diet consists of a variety of foods eaten in the right amounts.

You may want to have students recall the different food groups, which foods fall within a group, and the role of each one for our bodies (e.g. meat or beans being a source of protein, and protein being used to build and repair tissues in the body).



Water

Pupils may give this answer, state another drink instead, or give a food example with a high-water content (e.g. cucumber).

Whilst these other foods and drinks can be beneficial (e.g. vitamins in fruit juice), they might not contain enough water to reach the daily amount we need.

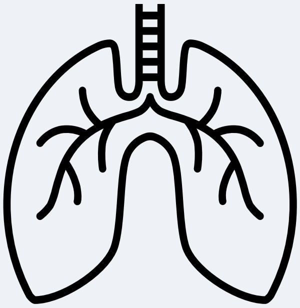
Water is important for our bodies. It keeps us cool by helping to regulate our temperature (the average body temperature is 37°C).

Nutrients and waste dissolve in the water in our blood, which is then circulated around the body, transporting the nutrients and waste.

Water helps chemical reactions happen inside of us. An example is during digestion when larger food molecules are broken down into smaller ones. The smaller molecules are then easily absorbed into the blood.

Oxygen

If 'air' is given as an answer, you should emphasise that humans (and most animals) need *oxygen* from the air to survive.



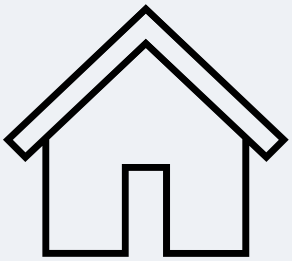
We breathe in oxygen, and it is used in a chemical reaction in our cells (which releases energy). This is important for life processes (e.g. growth, repair, digestion).

Carbon dioxide is produced as waste, and we breathe it out. Breathing requires the lungs.

Plants need carbon dioxide from the air for photosynthesis. Oxygen is produced as waste, which moves out of the plant through tiny holes (known as pores) on the underside of leaves. As plants do not have lungs, this process is *not* called breathing.

Some students may say that plants are important for survival because we use them for food (directly by eating or indirectly via energy flow in food chains/webs); therefore, carbon dioxide is needed in the air for plants.

This is a valid opinion, and you can discuss the role of plants as producers in food chains and webs. However, you should still emphasise that humans need oxygen from the air and that our bodies don't use carbon dioxide for any processes.



Shelter

Students may give this answer, a specific example, or say ‘protection’ or ‘safety’.

Others may refer to sleep or having somewhere warm, dry and/or protected from the weather, which links to shelter.

Almost all living things need shelter. Ask students about what shelter provides. It protects us from the environment and gives a safe place to sleep, which is important for our bodies to grow and heal properly.

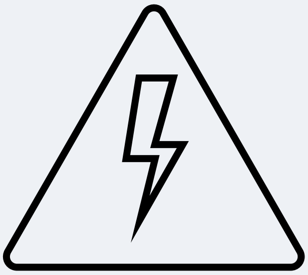
You could discuss examples of shelter in different habitats (e.g. houses in the UK have lots of insulation, but houses built in warmer climates don’t. They may even be painted white/light-coloured to reflect heat).

In space, shelter protects us against extreme temperatures, high radiation levels, and other risks like micrometeoroids (tiny bits of rock and metal).

Electricity/Power

Pupils may give this answer or an example of a device which requires electricity.

Electricity makes it easier to access the resources we need. You could ask students how they use electricity, making links to the previous answers.



For example, we use electricity to cook food, produce food packaging/containers, and build the transportation for moving food between locations. Electricity powers pumps that transport water from different sources to houses. It also powers the water treatment plants that make water safe for use.

In space, electricity would be used in the spacecraft/basecamp where humans live to run the systems that keep them alive (e.g. air pumps, water recycling).

Extension Task – Answer

All the resources are easier to get on Earth. Because the conditions (e.g. temperature, atmospheric composition and density) of the Moon and Mars are so different, we'd have to bring resources from Earth.

Whilst there is frozen water on the Moon and Mars, it would need to be extracted, transported to base, and made safe for use.

Electricity could be generated off-Earth (e.g. with solar panels). However, this – along with extracting frozen water – would require bringing equipment with us.

Activity: Essential or Extra

So far, students have considered the basics for survival. They will now consider what things make our lives easier or more comfortable.

Ask students 'What other resources would make astronauts feel happy, comfortable, and less homesick?'. You can lead a class discussion or use mini-whiteboards and select some students to share their answers.

The following prompt images are included in the PowerPoint presentation (on slide 6). You may wish to discuss some of the given information with your class.

Image: NASA

Some pupils may give a specific example of something they find fun (e.g. playing video games).

Spending time on fun activities can be good for our health.

It reduces stress and improves our mood, which helps our physical health too.

It can boost creativity and imagination, which might help us in other ways (e.g. finding a creative way to solve a problem when we get stuck).

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Exercise helps us stay healthy and live longer.

It strengthens bones and muscles; for the heart muscle, it improves blood circulation (cardiovascular health).

Our energy levels increase. Regular exercise is even good for our mental health and can help us sleep better.


Image: NASA

You could discuss how different types of exercise affect the body e.g. running improves cardiovascular health and stamina, lifting weights strengthens arm muscles.

You might ask students how exercise can be targeted based on age, career, or specific circumstances. For example, recovering from a broken bone requires not moving that part of the body while it heals, and since this will weaken muscles, a person might have physical therapy afterwards to build muscle strength.

Investigation 4 ‘How do we Stay Healthy in Space?’ will explore some types of exercises and training that astronauts complete.

Some pupils might give answers such as ‘family’ and/or ‘friends’, or ways in which we can speak to them (e.g. phones, computers).

You might discuss how being able to talk with others can help us feel supported; it can reduce stress and improve our mood, which helps our physical health too.

You could also highlight the importance of communication in other areas such as working together as a team and learning from each other.

For example, ground crews on Earth have regular contact with astronauts to get updates on how the mission is going and to help solve any problems that arise.

What Do Humans Need to Survive?

The next part involves the student workbooks. Students must tick the listed resources as 'essential' or 'extra'.

There are 2 blank spaces in the table that students can fill in with their own resources as an extension task. Ask them to explain why the resources are 'essential' or 'extra'.

The following table has information you could discuss with your class.

Resource	Answer	Information
Oxygen	Essential	Oxygen is used by our body's cells for life processes.
Pizza	Essential/ Extra	Food is essential. But we should prioritise taking food with the most nutritional value into space with us.
Pets	Extra	Many people don't have pets. But they can provide companionship and reduce loneliness and stress, which boosts physical and mental health.
Music	Extra	Whilst not essential, listening to music or playing an instrument is a form of entertainment, the benefits of which have been previously discussed.
Beds	Essential/ Extra	Sleeping in a comfortable bed lets us rest better, which is good for recovery and health. But some students may argue that you can sleep without a bed (e.g. using a sleeping bag when camping). Even so, this is still something to sleep in/with that keeps us warm, and this is especially essential in colder climates.
Hot Showers	Extra	Most people prefer the comfort of hot showers, but we can survive without them. However, there are different health benefits for both hot and cold showers.
Plants	Essential/ Extra	As producers, plants are an essential resource on Earth. But we don't need to take them into space – we can bring packaged food instead (though, ultimately, the food packs exist because of plants on Earth). Plants also give out oxygen – another essential resource. But in space, the life systems provide oxygen. On the International Space Station, oxygen is obtained from water.
Video Games	Extra	Whilst not essential, video games are a form of entertainment, the benefits of which have been previously discussed.

Activity: Comparing the Earth, Moon, and Mars

Thinking about the differences between the Earth, Moon, and Mars will help students understand the availability of resources and, therefore, plan what they need to include in their Moon Base.

Show students the comparison table from the PowerPoint presentation (on slide 9). You could discuss the data as a class using the following information.

The '*How to Use*' section details how students apply the data to complete the activity in their workbooks..

Average Temperature (^{o}C)

The unit of measurement is degrees Celsius. Temperature will vary depending on location, and the data takes this into account. Average temperatures for Earth and Mars have been calculated using both day and night temperatures as well.

Mars is colder than Earth because it's further from the Sun. It also has a thinner atmosphere, so heat is easily reflected back into space. Earth's thicker atmosphere acts like a blanket, reducing the amount of heat reflected, effectively 'trapping' it and keeping the surface warm.

The Moon's extreme temperatures are due to it having virtually no atmosphere. While atmospheres 'trap' some heat, they also protect against the Sun's intense radiation. Heat is scattered, limiting how much can pass through and reach the surface in the first place.

Without this protection, the Moon's surface scorches when facing the Sun and plummets in temperature when turned away.

How to Use

Students can complete the 'Average Temperature' scale. They can separate the temperatures given for the Moon into 'Moon (day)' and 'Moon (night)'.

Answer *– from hottest to coldest*: Moon (day), Earth, Mars, Moon (night).

Strength of Gravity (g)
The unit of measurement is g or g-force. 1g is the force a stationary object on Earth experiences.

The strength of gravity depends on the mass of an object. Mars is less massive than Earth, so has around 40% of Earth's gravity. The Moon is the least massive and has around 16% of Earth's gravity.

We might not notice it, but we work against gravity with each movement. In weaker gravity environments, our bodies don't need to work as hard, and our bones and muscles lose density and strength. That's why astronauts exercise every day when in space.

How to Use
Students can complete the 'Strength of Gravity' scale with this data.

Answer – *from strongest to weakest*: Earth, Mars, Moon.

Atmospheric Density (kg/m^3)
The unit of measurement is kilograms per metre cubed. Density is how much matter (mass, in kg) is in a certain space (volume, in m^3).

The data given is atmospheric density at the surface. This is sea level on Earth. Density decreases as distance upwards (altitude) increases. You could discuss this with students (e.g. how would breathing be affected?).

You can also link this data back to the average temperatures, using the explanations from that section.

How to Use
Students can complete the 'Atmospheric Density' scale.

Answer – *from thickest to thinnest*: Earth, Mars, Moon.

It is also a reason why humans cannot breathe on Mars or the Moon; the atmospheres are much thinner than Earth's.

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Atmospheric Composition
The data shows the percentage of gases that exist in each atmosphere. When discussing the similarities and differences, focus on the parts (e.g. nitrogen) as well as the amount (e.g. there is 78% nitrogen on Earth but only 2.5% on Mars).

However, consider atmospheric density too. For example, argon makes up 21% of the Moon's atmosphere compared to 2% of the Martian atmosphere. But the Moon's atmosphere is much thinner and contains less particles – and, therefore, less argon. It's like comparing 21% of 10 to 2% of a million.

How to Use
Students can use this in their explanations of why humans cannot breathe on Mars or the Moon. They should highlight the differences between the atmospheres, including how oxygen doesn't exist in the same abundance (21%) like it does on Earth.

Average Distance (km)
The unit of measurement is kilometres. Usually, distance is measured in metres, but kilometres has been used to simplify the numbers.

Distances in space are vast. Even a neighbouring planet like Mars is millions of kilometres away. The numbers would get bigger and more complex for each subsequent planet.

This is why astronomical units, like light-years (the distance travelled by light in 1 year; 300 million metres), are often used instead.

How to Use
Students can use this data to explain why we are testing our basecamp on the Moon before going to Mars.

Since the Moon is closer, communication is quick, supplies would arrive without too much delay, and it's much easier to evacuate (compared to Mars) if things go wrong. This lets us test the designs in a 'safer' location and make adjustments before building on Mars.

Activity: Sustainable Earth

Life hasn't been discovered anywhere else in the Universe. This suggests Earth's unique conditions (e.g. temperature, atmosphere, physical geography) are best for supporting life as we know it.

But extracting Earth's resources can damage our planet and impact the conditions we rely upon. This is unsustainable, especially when our increasing human population puts more demand on resources.

Ask students to reflect on these activities. The following prompt images are included in the PowerPoint presentation (on slide 13). You could discuss some of the given information with your class.

Humans produce a lot of waste that isn't always correctly disposed. Environmental harms of littering include microplastics in water, animals becoming sick/dying from ingestion, etc.

Even correctly disposed waste may end up in landfills, with toxins potentially being absorbed into the ground.

Water is an essential resource. But man-made dams and reservoirs can stop water from reaching needed areas.

Crops/animals used for food and other resources require water too (e.g. it takes 10 000 litres of water to produce 1 kg of cotton for clothing). If water demand is too high, it may run out in a certain location.

Image Link – Factory

Industries emit greenhouse gases (like carbon dioxide). These limit reflection of heat from the planet's surface, making Earth warm and liveable. But having too much in the atmosphere 'traps' more heat. This increases the planet's temperature and affects the water cycle.

Climate change (caused by global warming) increases the frequency of extreme weather events such as droughts.

Factories mass-produce resources, but they can cause air, land, and/or water pollution from toxic substances or through greenhouse gas (e.g. carbon dioxide) emissions.

Factories also use large amounts of electricity. Currently, most electricity is generated by burning fossil fuels. This releases carbon dioxide into the atmosphere.

Ask students which every-day items are factory-produced. You could debate if the benefits (e.g. short production times, convenience) outweigh any damages.

Image Link – Water Scarcity
Industries emit greenhouse gases (like carbon dioxide). These limit reflection of heat from the planet's surface, making Earth warm and liveable. But having too much in the atmosphere 'traps' more heat. This increases the planet's temperature and affects the water cycle.

Climate change (caused by global warming) increases the frequency of extreme weather events such as droughts.

Image Link – Deforestation
Mass production puts a strain on resources. Trees may be cut down for resources (e.g. paper, furniture), or to clear space for infrastructures such as factories.

Image Link – Mining
Mass production puts a strain on resources. Resources like minerals and metals are mined from the earth. An increased demand leads to more mining activities.

Large areas of forests are levelled to raise cattle or grow crops. Some land may be used for infrastructure instead.

Deforestation massively impacts the ecosystem. A direct effect is species losing their habitats, which can decrease populations and put them at risk of extinction.

Indirectly, carbon dioxide increases in the atmosphere. Trees are carbon sinks, absorbing and storing more carbon dioxide than they release. When cut down (and especially if burnt), carbon dioxide is emitted back into the atmosphere.

Image Link – Factory
Trees may be cut down for resources (e.g. paper, furniture), or to clear space for infrastructures such as factories.

Image Link – Mining
A forest may be cleared to mine resources from the ground beneath it.

Overfishing affects all other living things in the ecosystem.

Fish prey populations increase drastically since less are being eaten.

Fish predators may suffer population decreases if alternative food sources are lacking. Or, if they do hunt other species, those populations will decrease instead.

You could discuss food chains/food webs with your students, asking them about the consequences of certain changes. In a balanced ecosystem, population numbers of species may change slightly at certain points, but they remain stable over a longer span of time. If there is a drastic change, however, this can have consequences. Ultimately, a food web may collapse if put under too much strain.

Fishing can also damage habits of marine life, further disrupting the ecosystem. Boats might cause pollution through fuel use and plastic.

Many resources are extracted from underground.

This includes minerals (e.g. limestone that is used for construction), metals (e.g. copper which is used in many electronics), fossil fuels (e.g. oil, which is burned to generate electricity), and gemstones (e.g. diamonds used in jewellery).

Mining increases energy demand; fuel to run vehicles, electricity to operate equipment. Therefore, more fossil fuels are burned, increasing carbon dioxide in the atmosphere. Depending on the resource being mined, it can also cause land and/or water pollution.

Mining now happens more frequently due to population growth and upgrades to infrastructure and technology.

Image Link – Factory
Resources like minerals and metals are mined from the earth. An increased demand leads to more mining activities.

Image Link – Deforestation
A forest may be cleared to mine resources from the ground beneath it.

Ask students how we can live more sustainably. You might lead a class discussion or have students talk in pairs/groups before selecting some to share their answers. It may be useful for students to explain what makes their answer sustainable.

Students need to write their ideas in the workbooks. The following prompt images are included in the PowerPoint (on slide 14). You could discuss some of the following information with your class.

Recycling
Recycling correctly means waste isn't polluting the environment as litter or in landfill.

Less energy is used in recycling compared to production as well. Recycling a drinks can saves enough energy to power a TV for an hour.

A decreased energy demand means less burning of fossil fuels, so less carbon dioxide in the atmosphere.

Limiting Water Usage
Reducing usage means less water is transported and, therefore, less electricity is needed. Most electricity is generated by burning fossil fuels, so decreased demand leads to less carbon dioxide emissions.

Reduced water consumption means water will remain in rivers, lakes, etc., contributing to stable ecosystems. It ensures a greater supply in times of need (e.g. drought).

Reusable Bags
Bringing reusable bags to the shops reduces the demand on plastic bags and limits the number that ends up in landfill.

Plastics are made from fossil fuels, and their production emits greenhouse gases. By reducing how much plastic is produced, greenhouse gas emissions (and global warming) are limited.

Cycling
Walking or cycling (instead of using a car) is better for the environment and our health. Cars emit pollution, including carbon dioxide, when fuel is used. Less cars on the road means less carbon emissions, which limits global warming.

Using public transport also has the same effect. A full double decker bus effectively replaces up to 75 single occupancy cars.

Wind Power
This is one way electricity can be generated without emitting carbon dioxide. Others include solar, tidal and wave, geothermal, and hydroelectric. They are also renewable – this means they can be replenished, so will never run out.

Reducing carbon emissions can limit global warming, and using renewable power can secure electricity generation for the future.

You or your students may have thought of numerous more ways to be more sustainable. As well as the prompt images, the PowerPoint presentation includes some answers (on slide 15).

You could discuss with pupils which ideas are the most feasible. For example, some regions do not have good public transport links. Other areas may have a limited diversity of wildlife to care for, or perhaps pupils don’t have access to outdoor space at home.

Other factors to consider are the cost, effort, and the time expense involved, as well as individual abilities and circumstances.

Emphasise to students that no single person can do everything, but lots of people making small contributions can still make a big difference.

Activity: Basecamp Design

Show students the video from the PowerPoint presentation (on slide 16) that explains water recycling on the International Space Station. You should emphasise that water was first brought in bags. Ask students what else they'd need bring, linking the availability of resources to the comparison of Earth, Moon, and Mars activity.

The student workbook includes a design template for a Moon Base. It has 9 rooms/modules of varying shapes and sizes, and pupils assign each of the listed features (see table below) to a room/module.

Students detail the items contained within them (by drawing, labelling, etc.), considering the number of people living in their Moon Base and how this affects the facilities needed.

You could discuss some of the following information with your class.

Feature	Information
Food Supply Room	Food must be nutritional and not perish easily/quickly. Student might consider food packaging and how to store food. Ask pupils if any of them have been camping and discuss the food they ate. Initially bringing food is vital, however long-term sustainability should be considered. Sending resupplies to the Moon would take around 3 days – for Mars, it could take months. This also uses a lot of fuel. Growing crops is an alternative. Ask students about plant requirements and how to recreate those conditions on the Moon and Mars.
Water Systems Room	The earlier video gives some information about what could be included in this room. You might also link to students' knowledge of separating techniques (if the topic content has been previously taught). Students could consider the proximity of specific rooms as well. A lot of water is used in the bathroom, so placing the water systems room beside it means water can be returned and recycled quickly. If crops are grown, then placing the water systems room and food supply room together ensures the plants receive water quickly.

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Feature	Information
Communications Room	People at the Moon Base must be able to contact Earth. Ask students how they communicate with others when they're apart e.g. mobile phones, internet. Many communication systems (TV, radio, Wi-Fi, etc.) use radio waves to send and receive data, audio, and images/videos. The International Space Station (ISS) communicates with Earth via radio waves. A network of satellites transmits signals and data between the ISS and our planet. Students may include objects in this room like computers, cameras, microphones, radio antennae, or a satellite dish.
Bedroom	Students should consider what is needed for restful sleep and how many people will be living in their Moon Base. Astronauts on the International Space Station (ISS) often have trouble sleeping. One reason is because the ISS orbits the Earth 16 times a day, so experiences 16 sunrises and sunsets. The Moon spins on its axis much slower than Earth. It takes 29.5 Earth days for the Moon to complete 1 full rotation (1 lunar day). There'll be periods of total darkness and total brightness. A Martian day, in comparison, is only 36 minutes longer than Earth's. However, astronauts work in shifts around the clock, so some may need to sleep whilst it's still bright outside regardless of being on the Moon or Mars. To help with this, students might have artificial lighting in their base and put shutters on any windows they want to add. Another reason for lack of sleep is the loud equipment – especially air fans on the ISS. Placing the bedroom away from noisier rooms could minimise this.
Bathroom	Students could consider the number of facilities in the room and the location of the room in the base. For example, they might place the bathroom next to the water systems room so water can move quickly between them.

What Do Humans Need to Survive?

Feature	Information
Living Quarters with Kitchen	Students should include kitchen appliances and items for entertainment. Ask them how they relax or have fun and consider the feasibility of bringing certain items e.g. a drum kit compared to a handheld games console. Students could consider the location of the room. Placing it near the food supply room is the most convenient option.
Electricity/Power Supply Room	Most electricity on Earth is produced by making a turbine spin to power a generator. Heat from burning fossil fuels turns water into steam. This passes through a turbine and makes it spin. Similarly, wind turns the blades of wind turbines. But the Moon has virtually no atmosphere, so no wind. Creative ways of spinning a turbine include exercise bikes hooked up to generators or water running past turbine blades when it's being transported. But this probably won't generate a lot of electricity. Solar panels are the best option. They absorb energy from the Sun, causing a current to flow. Batteries can store excess electricity for use when needed (such as during the nighttime period). Some students might have already considered using power packs or batteries in some way.
Medical Room with Gym and Air Supply Systems	It isn't feasible to bring certain medical equipment/supplies. For example, an ultrasound scanner can be transported much easier than a big and heavy MRI machine. The limited available space also means only taking that which is most useful and needed. Ask students about what is included in a first aid kit to help prompt some ideas if needed. The gym should include equipment for maintaining muscle and bone strength, as this weakens in lower gravity environments. But other ways to stay healthy can be included as well. Students don't need to give lots of detail about the equipment for the air supply systems. There should just be an understanding that the Moon's atmosphere is unsuitable for humans, so we'll need to recreate one like Earth's. This may include using oxygen generators or oxygen tanks. Fans can be added to move air throughout the base, and filters are needed to get rid of exhaled waste carbon dioxide.

Feature	Information
Science Lab	Ask students to think about science experiments they could carry out on the Moon or Mars and what equipment is needed. You can make a link to 'Investigation 3: How do you control a robot rover?', which involves using a rover to explore the Martian surface and find out more about the conditions there. Some examples of experiments happening on the International Space Station (ISS) include: • Understanding how our bodies change in low-gravity environments • Exploring how microbes behave in space • Exploring how plants grow in space • Testing out water purification methods • Monitoring Earth from a different perspective (e.g. looking at atmosphere, oceans, land, etc.) Another idea is studying rocks and other samples from the surface of the Moon or Mars. This could be to better understand the formation of these bodies, to look for signs of water, etc.

Once designs are completed, students can reflect on their favourite aspect of the Moon Base and write an explanation in the workbook of how it will help them live happily and healthily in space.

Extension Ideas

If you wish to explore the content from this investigation further, we have a list of suggested ideas below:

- Give students a range of materials to create a model of their base
- Grow different plants on the classroom windowsills to test which conditions support the best growth
- Have students write a diary entry about daily life in their Moon Base and describe the rooms and equipment
- Discuss how to make the classroom or school more sustainable and choose actions to take (students could design posters, speak in assemblies, etc.)

Investigation 4

How Do We Stay Healthy in Space?

Learning Objectives

- To know some of the dangers of human space exploration
- To practice and develop key physical skills
- To evaluate performance and recognise success

Career Link: Medic/Nutritionist/Physical Trainer

Curriculum Links

Subject	Topic	Year	Topic Elements
Mathematics	Measurement	Year 3	Measure, compare, add and subtract: lengths (m/cm/mm); mass (kg/g); volume/capacity (l/ml)
			Record and compare time in terms of seconds, minutes and hours
			Compare durations of events
		Year 4	Convert between different units of measure
		Year 5	Convert between different units of metric measure (for example, kilometre and metre; centimetre and metre; centimetre and millimetre; gram and kilogram; litre and millilitre)
		Year 6	Use, read, write and convert between standard units, converting measurements of length, mass, volume and time from a smaller unit of measure to a larger unit, and vice versa, using decimal notation to up to three decimal places

Subject	Topic	Year	Topic Elements
Physical Education		Key Stage 2	Use running, jumping, throwing and catching in isolation and in combination
			Develop flexibility, strength, technique, control and balance
			Compare their performances with previous ones and demonstrate improvement to achieve their personal best
Science	Working Scientifically	Lower Key Stage 2	Making systematic and careful observations and, where appropriate, taking accurate measurements using standard units, using a range of equipment, including thermometers and data loggers
			Gathering, recording, classifying and presenting data in a variety of ways to help in answering questions
		Upper Key Stage 2	Taking measurements, using a range of scientific equipment, with increasing accuracy and precision, taking repeat readings when appropriate

Lesson Plan

Possible Student Misconceptions:

- There is no gravity in space
- Living in space doesn't affect the human body

Materials:

- Student Workbooks
- Pens/Pencils for students
- Resources for each chosen activity (see specific activity section for a list of equipment)
- Optional: Teacher Handbook (see referenced pages for more information/guidance)

Duration	Activity	Pages	Materials
10 minutes	Students change into PE kits and go to where the lesson will take place.		
5 minutes	Recap the last investigations and how this connects to the current investigation and overall Mars project. Read the information in the student workbooks (*Some Dangers of Human Space Exploration*) to contextualise why astronauts undergo training.	Teacher Handbook: 35 Student Workbook: 28 – 29	Student Workbooks
5 minutes	Perform a warm-up with students.		
30 minutes	Have students complete the chosen activities. This can be done in a circuit training style, or by splitting the class into pairs/groups and performing the activities together one after another.	Teacher Handbook: 36 – 51 Student Workbook: 30 – 45	Student Workbooks Pens/Pencils Resources for each chosen activity
10 minutes	Perform a cool-down with students before they change back into their school uniforms.		

How does it link to the Mars project?

In previous investigations, students discovered how to find good locations for bases off-Earth and what needs to be included in their design. They also learned how we can use robot rovers to explore regions beyond our base and/or too dangerous for humans.

In this investigation, students will act as health professionals and explore how training is fundamental to a successful mission – not only to keep ourselves healthy, but to work efficiently as well.

We must understand the effects of alien environments on the human body and how to reduce any negative impacts. Astronaut training also incorporates drills to practice key aspects of the job role (e.g. exercises to improve reaction times, learning how to manoeuvre in spacesuits).

Staying healthy lets us live in our base for longer and work to the best of our abilities, which increases the chances of a successful mission.

Investigation Overview

Students will learn about some of the risks associated with human space exploration and how astronauts prepare for these. They will then perform activities that simulate different aspects of astronaut training.

Some highlight different skills astronauts need, and others focus on how astronauts deal with issues of the space environment.

These are from the '*Mission X – Train Like an Astronaut'* project, which is supported by the European Space Agency (ESA) and UK Space Agency (UKSA) and facilitated by European Space Education Resource Offices (ESEROs) and volunteer national organisers.

The Schools' Observatory have adapted the activities to cut down their duration and so that they better suit students taking measurements and using their workbooks.

There are also questions for pupils to reflect on their results and draw conclusions/make links between results and the wider world. These can be completed as students do the activity, or afterwards once pupils are back in a classroom.

8 activities have been selected that link best with our project. The student workbooks contain all activities (including instructions, a results table, and questions to answer). However, not all activities need to be completed for the investigation. You can choose based on school resources and facilities, class size, individual pupil needs, etc.

The activities can be done in a circuit training style, with pupils moving from activity to activity in a carousel. Alternatively, split your class into pairs/groups and perform each activity together one after another.

Further information and guidance is provided in the specific sections for each activity.

Information: Some Dangers of Human Space Exploration

The student workbook has information about some of the dangers involved in human space exploration.

You should read this with your class to highlight that astronaut training is crucial for safe and successful missions. Students can think about these dangers as they complete activities. At the end, ask how each activity relates to and helps reduce risks associated with the dangers.

For example, ‘The Speed of Light’ activity tests reaction time. This is important when travelling in a rocket (to perform manoeuvres at the right time) and when wearing spacesuits in the space environment (to complete tasks quickly in the limited time available).

Activity: Mission Control

Physical Skills – balance, concentration, coordination, hand-eye coordination, reaction time, stability.

Equipment – tennis ball (or similar), stopwatch.

Student Workbook – pages 30 and 31.

Overview

Students balance on one leg, repeatedly throwing a ball at the wall. They record the time it takes until they lose balance or drop the ball. On their next turn, they swap legs and repeat the activity.

The results table includes 3 attempts on each leg; however, some can be left blank if time runs out. But students must have at least 1 result recorded for each leg to compare and reflect on their balance.

This activity may be easier in pairs, with one student performing the task and the other using the stopwatch.

Astronaut Training Context

Balance is affected by gravity. We don't notice this on Earth, as we've adapted to the conditions of our planet – such as its gravitational field. However, the strength of gravity depends on the mass of the object. The bigger the mass, the stronger its gravitational pull.

Both the Moon and Mars are less massive than Earth, so their gravitational fields are weaker. The smallest is the Moon, which has around a sixth (~16%) of the gravity we experience on Earth. Mars has around two fifths (~40%) of Earth's gravity.

With less force pulling us downwards, our sense of balance needs time to adjust. Astronaut training includes exercises that focus on balance and spatial awareness, which hopefully helps to reduce any initial disorientation and nausea from being in a lower-gravity environment.

Student Workbook Answers
Along with answers, the following information gives further detail and possible discussion points to share with your students.

Did you balance better on your left or right leg?
This will be different for each student. The leg may or may not be on the same side as their dominant hand.

How do your results show that you balanced better on that leg?
Students should find their times are longer for either the left or right leg. This is the side with better balance.

Why might your balance be better on that leg compared to the other?
When walking or standing, we can unconsciously put more weight on one leg, making the muscles stronger. This makes it easier for that leg to support us when balancing. A weaker leg may shake when we put our weight on it, making it difficult to balance.

The activities we do can also influence muscle strength. For example, when playing football, the dominant foot is used to control and kick the ball. The other leg is used as support, which can improve balance on that side over time.

Focus is important too. If we think we're worse at balancing on one side, we tend to concentrate more and so might do better compared to the opposite side.

As the students are performing the activity with others around, this could be distracting and cause them to lose balance quicker as well.

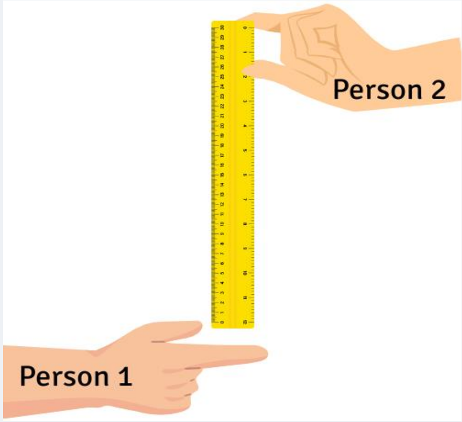
Activity: The Speed of Light

Physical Skills – concentration, fine-motor skills, hand-eye coordination, reaction time.

Equipment – 30cm ruler.

Student Workbook – pages 32 and 33.

Overview



Students work in pairs to measure their reaction time using a ruler-drop test.

One student holds out their dominant hand, and the other lines up the 0 cm mark on the ruler with the top of the thumb.

The ruler is dropped without warning, and the student catches it between their thumb and index finger.

The distance is recorded and then compared to the closest value in a Distance-Time chart, which gives a reaction time.

The results table includes 3 attempts; however, some can be left blank if time runs out.

Astronaut Training Context

Astronauts must be prepared for unexpected situations. They need to respond quickly to sudden changes and minimise the risk of dangers that arise. During training, they perform exercises to improve their hand-eye reaction time.

This not only prepares them for hazardous events, but it also helps them when operating the robotic arm on the International Space Station or completing spacewalks (Extra-Vehicular Activities/EVAs) outside the station.

Student Workbook Answers

Along with answers, the following information gives further detail and possible discussion points to share with your students.

The standard unit of distance is metres (m). 1 m = 100 cm. Calculate your average distance in metres.

Divide the average distance by 100 to convert into metres.

The standard unit of time is seconds (s). 1 s = 1000 ms. Calculate your average reaction time in seconds.

Divide the average reaction time by 1000 to convert into milliseconds.

What could have a negative effect on your reaction time and make it worse?

Some activities can help improve reaction time, but lifestyle factors also have an influence. Lack of sleep causes fatigue and slows down our reactions. Alcohol and certain drugs slow reaction time too.

Having better physical fitness has also been linked to faster reaction times, while dehydration can impair cognitive function and result in slower reactions.

As we get older, the number of neurons in the brain decreases, and this worsens our reaction time.

Reaction time also changes depending on which sense the stimulus is triggering. This is because the time taken for the stimulus to reach the brain is different for each sensory type. People tend to react quicker to sound than light, while reaction time to touch is the slowest.

Distractions in the environment, such as background noise, will increase reaction time as well.

Activity: Planet You Go, Gravity You Find

Physical Skills – coordination, strength.

Equipment – 3 balls of varying masses (e.g. 0.5 kg, 1 kg, 1.5 kg) labelled A, B, and C; stopwatch.

Student Workbook – pages 34 and 35.

Overview

Students squat while holding a ball and jump forwards, lifting it above their head. They record the time taken to cover a set distance and repeat with the other balls. The different masses simulate different gravitational conditions.

You can measure out the distance covered (e.g. 3 metres) or mark out a start and end point (e.g. between 2 cones). But the distance must remain the same throughout the activity.

The results table includes 1 attempt for each ball. This activity may be easier in pairs, with one student performing the task and the other using the stopwatch.

Astronaut Training Context

Astronaut train in different simulated gravity environments (to prepare for these changes). On the International Space Station, they experience weightlessness due to the its orbit around the Earth; it's in constant freefall.

If we feel less gravity, it's because a smaller force is pulling us down, so our bodies don't work as hard to overcome it. This decreases muscle and bone density, which is why astronauts continue to exercise whilst in lower gravity environments.

They also feel different g-forces during rocket travel. 1-G is the force a stationary object on Earth feels. Up to 3-G can be experienced when taking off and re-entering Earth's atmosphere.

Student Workbook Answers

Along with answers, the following information gives further detail and possible discussion points to share with your students.

Which ball was the easiest to jump with?

The lightest mass ball is easiest to jump with. The correct letter depends on how you've labelled them.

How do your results show which ball was the easiest to jump with?

The time taken for this ball is the quickest.

Imagine you lifted the same object on Earth, on the Moon, and on Mars. Which ball matches what it would be like to lift the object in these places?

Earth: ball with largest mass, Moon: ball with smallest mass, Mars: ball with medium mass

Explain your answers. Include data (the time) from your results table.

The Earth, Moon, and Mars have different gravitational field strengths because they are different masses. Therefore, the force needed to lift the same object on each of them is also different.

Earth is the most massive, so has the strongest gravitational pull. The largest mass ball modelled lifting the object on Earth. This should be their longest time.

The next most massive is Mars. Its strength of gravity is around two fifths (~40%) of Earth's. The medium mass ball modelled lifting the object on Mars. This should be their next longest time.

The least massive is the Moon. The strength of gravity is around a sixth (~16%) of Earth's. The smallest mass ball modelled lifting the object on the Moon. This should be their quickest time.

Activity: Crew Assembly Training

Physical Skills – communication, dexterity, hand-eye coordination, teamwork.

Equipment – 1 pair of boxing gloves per student. Alternatively, they can wear 2 pairs of other gloves (e.g. winter, fabric, disposable, rubber, football, etc.) or a combination instead; building pieces (e.g. blocks, stacking cups); stopwatches; optional: mats, hula hoops, etc.

Student Workbook – pages 36 and 37.

Overview

Students wear thick gloves to simulate wearing bulky spacesuits. They are split into at least 2 teams and record the time taken for them to build a structure (block tower or stack of cups).

Each teams forms a line at a starting area, referred to as ‘Basecamp’. There is an ‘Assembly Area’ a small distance (e.g. 3 metres) away. Measuring the distance isn’t necessary, but it must be the same for all teams. You could use mats/hula hoops/other objects to mark these areas for students.

The building blocks/stacking cups are placed at the back of the student line. Students pass along a piece until it reaches the person at the front. They take it to the Assembly Area and return to the back of the line at Basecamp. This process is repeated until the structure is built.

If the structure falls, one student is nominated by the team to go to the Assembly Area and fix it. Students note down if this happens and a 10 second penalty is awarded each time, with this added to their total at the end.

The results table includes space to record the completed time, the number of penalties (that students will tally mark), the penalty time, and the total time (both calculated by students).

Astronaut Training Context

Astronauts need good dexterity and hand-eye coordination to assemble devices and use objects during their missions. Some do spacewalks (extra-vehicular activities/EVAs), which requires manipulating tools while wearing spacesuits. They practice this in training, learning how to use tools wearing thick and bulky gloves.

Teamwork skills are also essential. Astronauts spend a lot of time together as a crew onboard small spacecrafts. To complete tasks efficiently, they must communicate and support each other. This is especially important during EVAs, as spacesuits can only be worn for up to 6 or 7 hours – working well together maximises performance output during the limited timeframe.

Student Workbook Answers

Along with answers, the following information gives further detail and possible discussion points to share with your students.

Give one way your team worked well together and one way you could improve.

Use some of these prompt questions to help student reflection:

- Did you assess the strengths and weaknesses of everyone in your team? (e.g. a person might have been slower getting to the Assembly Area, but much better at stacking the blocks/cups).
- Did your team plan the order of people (i.e. who went first, second, etc.)?
- Would it have been helpful to have a team leader? Why? What could this person do to improve how your team works?
- How did your team communicate? Did anyone shout at others? Was everyone listened to when they spoke?
- If your structure fell, how did you respond as a team? Did you still put in the same effort afterwards, or did you not try as much?
- How did your team support each other? Did you cheer each other on? Did you say encouraging things if a team member had a set back?

Activity: Astro Agility Course

Physical Skills – agility, balance, coordination, spatial awareness.

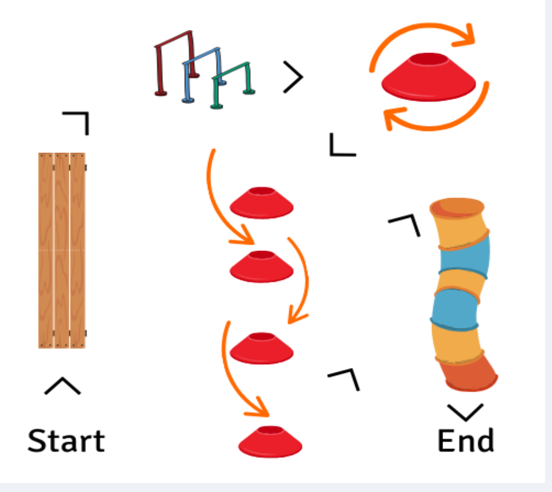
Equipment – cones, agility ladder, hula hoops, hurdles, tunnels, or other similar objects; stopwatch; optional: tape (to guide students around the course).

Student Workbook – pages 38 and 39.

Overview

Students complete an agility course that tests their balance and coordination, recording the time taken. If an object is knocked over/moved out of place, a 2 second penalty is awarded each time. This is added to their total at the end.

The example course (on the right) is set out as follows: students walk across a bench, jump over hurdles, run around a cone, weave between a series of cones, and then crawl through a tunnel.



The design and layout of the agility course can be modified to suit your class, location of the lesson, available resources, etc.

The results table includes 3 attempts; however, some can be left blank if time runs out.

This activity may be easier in pairs, with one student performing the task and the other using the stopwatch and keeping count of penalties.

Astronaut Training Context

Astronauts experience different forces of gravity. On the International Space Station, they experience weightlessness due to the its orbit around the Earth; it's in constant freefall.

They also feel different g-forces during rocket travel. 1-G is the force a stationary object on Earth feels. Up to 3-G can be experienced when taking off and re-entering Earth's atmosphere.

These different environments affect balance and body control, impacting how quickly astronauts react to situations and events. Agility is tested before and after missions so scientists can understand any changes and hopefully mitigate these in the future.

Student Workbook Answers

Along with answers, the following information gives further detail and possible discussion points to share with your students.

What was the most challenging part of the Astro Agility Course? How could you improve your performance on this part?

Challenges will depend on how you've built the Astro Agility Course and individual student ability.

However, certain exercises/drills can enhance agility overall. These involve quick changes in speed and direction (e.g. agility ladder, side shuffles/steps, shuttle runs, skipping rope exercises, and high knees).

Students should link their challenges to the relevant skills for improvement (e.g. exercises to strengthen leg muscles if they struggled to jump over hurdles, exercises to improve cardio if they became tired partway through the course, etc).

After each attempt, times may improve since the course is more familiar. But it could also increase because of fatigue.

Activity: Crew Strength Training

Physical Skills – balance, endurance, strength.

Equipment – stopwatch/timer.

Student Workbook – pages 40 and 41.

Overview

Students count the number of squats and push-ups they can complete in 30 seconds. Results are then compared to assess the difference between upper-body and lower-body muscle strength.

The results table includes 3 attempts for both squats and push-ups; however, some can be left blank if time runs out.

This activity may be easier in pairs, with one student performing the task and the other using the stopwatch.

Astronaut Training Context

The strength of gravity depends on the mass of the object. The bigger the mass, the stronger its gravitational pull.

Both the Moon and Mars are less massive than the Earth, so their gravitational fields are weaker. The smallest is the Moon, with around a sixth (~16%) of the gravity we experience on Earth. Mars has around two fifths (~40%) of Earth's gravity.

In weaker gravity, a smaller force is pulling down, so our bodies don't work as hard to overcome it. This decreases muscle and bone density.

Astronauts exercise before, during, and after spending time in lower gravity environments. This includes cardiovascular exercises and weight bearing activities to strengthen muscles and bones.

Student Workbook Answers

Along with answers, the following information gives further detail and possible discussion points to share with your students.

Do you have better upper-body or lower-body strength? Use your results to explain your answer.

If students performed more push-ups than squats in 30 seconds, this shows they have better upper-body strength.

If students performed more squats than push-ups in 30 seconds, this shows they have better lower-body strength.

What exercises would improve the strength in the weaker part of your body?

Exercises that improve upper-body strength include:

- Arm raises (front and side)
- Burpees
- Plank
- Pull-ups
- Lifting weights/dumbbells (e.g. bicep curls, overhead press)
- Rowing
- Wall press-ups

Exercises that improve lower-body strength include:

- Lunges (front and side)
- Glute bridge
- Step-ups
- Calf raises
- Leg lifts (front and side)

Activity: Jump For The Moon

Physical Skills – balance, coordination, endurance.

Equipment – stopwatch/timer, skipping rope.

Student Workbook – pages 42 and 43.

Overview

Students measure their heart rate and then skip with a rope for 1 minute. Their heart rate afterwards is also measured for comparison.

To measure heart rate, students count their heartbeat for 10 seconds and then multiply by 6.

The results table includes 3 attempts; however, some can be left blank if time runs out. This activity may be easier in pairs, with one student performing the task and the other using the stopwatch.

Astronaut Training Context

The strength of gravity depends on the mass of the object. The bigger the mass, the stronger its gravitational pull.

Both the Moon and Mars are less massive than the Earth, so their gravitational fields are weaker. The smallest is the Moon, with around a sixth (~16%) of the gravity we experience on Earth. Mars has around two fifths (~40%) of Earth's gravity.

In weaker gravity, a smaller force is pulling down, so our bodies don't work as hard to overcome it. This decreases muscle and bone density, and since the heart is a muscle, it can weaken.

Astronauts exercise before, during, and after spending time in lower gravity environments. This includes cardiovascular exercises and weight bearing activities to strengthen muscles and bones.

Student Workbook Answers
Along with answers, the following information gives further detail and possible discussion points to share with your students.

How did your heart rate change after skipping for 1 minute?
Students should find that their heart rates increase. The biggest increase might be after the first attempt, though this could depend on what activity they were doing previously (if it was more strenuous, their heart rate may still be recovering).

This is because they're at their most 'rested' before attempt 1. After skipping once, the rest period between attempts may not be sufficient to return their heart rate back to its resting rate, so the change will be lower for these subsequent attempts. However, it should still increase.

Why did this change happen?
A higher heart rate means the heart is beating more per minute. This happens during exercise because oxygen demand increases.

Muscles need more oxygen when we exert ourselves, and oxygen is delivered via the blood. The heart must beat faster to pump the required oxygenated blood to our muscles. Because blood is circulating faster, waste products like carbon dioxide can also be quickly removed.

Our breathing rate (and depth) increases too. This allows us to breathe in more oxygen per second and breathe out waste carbon dioxide.

Regular exercise makes the heart muscle stronger. A stronger heart can squeeze harder, pumping out more blood with each beat. This means the same amount of oxygenated blood can be circulated through the body in less heartbeats, which is more efficient.

So, for those who exercise often, their heart rate doesn't have to increase as much to fulfil the demand for oxygen.

Activity: Do a Spacewalk

Physical Skills – coordination, dexterity, flexibility, strength.

Equipment – tape measure (or alternative way to measure distance), object marker (e.g. cone).

Student Workbook – pages 44 and 45.

Overview

Students perform a crab walk (from sitting on the ground with knees bent, they put their arms and hands behind them and then lift up), travelling as far as they can before falling down. An object marker is placed on this end spot, and the distance is measured with a tape measure (or other piece of equipment).

If students reach the edge of the designated activity area, they need to turn around and travel back to the start, repeating as often as necessary.

The results table includes 3 attempts; however, some can be left blank if time runs out. This activity may be easier in pairs, with one student performing the task and the other placing the object marker down.

Astronaut Training Context

Astronauts may complete spacewalks (extra-vehicular activities/EVAs). They wear bulky spacesuits for up to 6 or 7 hours at a time, relying on their coordination and strength to move around. The spacesuits have large, thick gloves, so good dexterity is important.

To practice these strenuous movements, astronauts train underwater while wearing their spacesuits, performing the kinds of tasks they'll do on their mission.

Other parts of their training also focus on developing their muscle strength and coordination.

Student Workbook Answers

Along with answers, the following information gives further detail and possible discussion points to share with your students.

What exercises might help you to improve and travel a further distance?

Performing a crab walk uses lots of different muscles. Some of these include muscles in the shoulders and arms (e.g. triceps), the legs (e.g. calves, quadriceps, gluteal), and core muscles (e.g. abdominal).

Students' answers may focus on exercises to target these muscles. They might also give examples of exercises that improve balance and flexibility, especially in the hips, shoulders, wrists, and ankles.

Extension Ideas

If you wish to explore the content from this investigation further, we have a list of suggested ideas below:

- Try out some other activities from the *Mission X* project
- Collate the class data for one (or more) of the activities and have students display the data by drawing graphs
- Research the nutritional requirements for an astronaut and have students plan a 'Space Meal' to meet thee dietary needs

Evaluation

It would be helpful for the evaluation of this project if you were able to run 2 additional creative activities with students at the end of the 6 workshops. These are designed to give students a sense of belonging about who STEM subjects are for, and to allow them to display some of the knowledge they have learnt.

Me on Mars

Ask the students to create a creative artwork (you can direct the medium and form) that shows themselves as an astronaut on the surface of Mars.

First Steps

Ask the students to create a creative writing piece (you can direct the medium and form) that brings their imagination to life. What would it be like to be the first human to set foot upon the Martian surface? What is it like? What can they see? How do they feel?

We will ask to collect a random sample of the work from your class – these can be copies or photographs of the work and do not need to be the originals.

Appendix 1

Student Account Details

Student Account Details

Student Accounts

The following table is provided to record details of students' accounts.

Student Name	Username	Password

Student Account Details

Student Name	Username	Password

Appendix 2

Extension Activities (STEM Professional Led Investigations)

Appendix 2: Extension Activities

If you wish to further explore the content from the STEM professional led investigations, please find the suggested ideas in the relevant sections.

Note: Underlined text is hyperlinked – please open the online version of this handbook to explore these in more detail.

Investigation 1: Where Should We Build a Moon Base?

- Timeline of the Apollo Missions: Students can explore key events in the Apollo programme. This helps them understand how humans first reached the Moon and what was learned from these missions.
- Make Your Own Impact Crater: A hands-on experiment where students drop different objects into flour or sand to see how craters form. They can investigate how the size, speed, and angle of impact affect the crater shape.
- Measure the Mountains on the Moon: An interactive activity where students use digital tools to measure the height of lunar mountains and compare them to Earth's mountains, reinforcing spatial reasoning and data skills.
- What Can We See on the Moon?: Students can watch this video to discover the many different features on its surface.
- Why Does the Moon Have Phases?: An animated explanation of the Moon's orbit, how sunlight hits it, and why we see it change shape over a 29.5-day cycle. Reinforces understanding of Earth–Moon–Sun relationships and introduces lunar months.
- Moon Phases Poster: A large, printable poster showing each lunar phase (e.g., new moon, crescent, quarter, gibbous, full). This is great for classroom display or to help students visually connect their Moonsaic observations to the Moon's cycle.

Investigation 3: How Do You Control a Robot Rover?

- Pupils draw and label their own Mars rover design. Encourage them to think about the tools it would need (e.g., a drill, camera, weather sensor).
- Ask students to write a short diary entry as if they are a rover on Mars, describing what they see, what they measure, and how they "feel" as a robot.
- Provide images of the Martian surface (e.g., from NASA or The Schools' Observatory). Pupils can identify features such as craters, valleys, and volcanoes, and plot possible rover routes on a map.
- Set a creative writing task: "The Day I Landed on Mars." Pupils use imagination but include at least one scientific fact they've learned about Mars.
- Give pupils simple Mars datasets (e.g., daily temperatures, dust storm speeds). Ask them to plot graphs or compare averages. This ties into maths and science skills.

Investigation 5: Why Does Mars Change Size?

- Students can covert their distances into miles
- Make a Play-doh Solar System showing the sizes of the planets to scale
- Use The Schools' Observatory's online software to Investigate the Size of a Planet
- Use The Schools' Observatory's online tool to Calculate the Speed of the Planets
- Have students research how our understanding of the Solar System has changed over time (you may want to use information from The Schools' Observatory's website)

Investigation 6: When Should We Launch to Mars?

- Have students design a mission patch. These are created for every space mission and usually have the crew's names along with some images which explain a little about what the mission is for.

Appendix 3

Student Skills Audit

Appendix 3: Student Skills Audit

Skills Audit	Workshop							
	1	2	3	4	5	6	Evaluation Activities	
Reading with understanding	X	X	X	X		X		
Discussion and explanation from text	X	X						
Writing	X	X						X
Noticing and interpreting details, patterns, and changes	X	X	X	X	X	X		
Speaking and communication	X	X		X				X
Listening and responding	X	X	X	X	X			
Solving number problems					X	X		
Works with fractions, decimals, percentages		X			X			
Measuring accurately				X	X	X		
Interpreting data and critical thinking		X	X	X	X	X		
Appling maths to real-life problems						X		
Planning and conducting investigations	X		X		X	X		
Understanding key topics	X	X			X	X	X	X
Recording and interpreting results			X	X	X			
Using scientific vocabulary	X	X			X	X		
Writing and debugging simple code			X					
Understanding how networks work	X		X					
Using technology to create or research	X		X			X		
Understanding the position of objects in space and how they move	X		X	X	X	X		
Working independently	X	X		X	X		X	X
Solving problems			X			X		
Reflecting on learning	X	X	X				X	X
Managing time	X		X					
Learning about a variety of professions	X	X	X	X	X	X		
Team working	X	X		X		X		
Understanding civic responsibility		X						
Exploring ideas through art	X	X					X	
Participating in PE and sports				X				
Showing creativity and imagination		X					X	X
Understanding environmental issues and sustainability	X	X				X		
Understanding diversity and cultural differences	X		X					
Participating in decision-making	X		X			X		

Appendix 4

Gatsby Benchmarks

Gatsby Benchmarks – Good Career Guidance

The project aligns with the following Gatsby Benchmarks for Good Career Guidance:

Benchmark	Criteria
3. Addressing the needs of each young person	A school's careers programme should actively seek to challenge misconceptions and stereotypical thinking, showcase a diverse range of role models and raise aspirations.
4. Linking curriculum learning to careers	Every year, in every subject, every pupil should have opportunities to learn how the knowledge and skills developed in that subject helps people to gain entry to, and be more effective workers within, a wide range of careers.
5. Encounters with employers and employees	Every year, from the age of 11, pupils should participate in at least one meaningful encounter with an employer.
7. Encounters with further and higher education	By the age of 16, every pupil should have had meaningful encounters with providers of the full range of learning opportunities, including sixth forms, colleges, universities and ITPs.

Gatsby and other organisations also developed the 'Skills Builder Universal Framework' which offers employers/employees/young people a common approach to develop and describe transferable essential skills.

These skills are listening and speaking (grouped as 'Communication'), problem solving and creativity (grouped as 'Creative Problem Solving'), adapting and planning (grouped as 'Self-Management'), and leadership and teamwork (grouped as 'Collaboration').

The skills also align well with those from our Student Skills Audit.

Gatsby Benchmarks – Good Practical Science

The project aligns with the following Gatsby Benchmarks for Good Practical Science:

Benchmark	Criteria
2. Purposeful Practical Science	Teachers should have a clear purpose for every practical activity and know how it relates to the rest of what they are teaching.
	Teachers should plan to their satisfaction how to introduce each practical and how to follow it up.
3. Expert Teachers	At pre-16 level, if teachers do not have a post-A level science qualification related to the subject they teach, they should have had sufficient additional training to give them the confidence, subject knowledge and skills to conduct effective practical work at that level.
4. Frequent and varied practical science	Practical activities can be short or long. There should be enough long science lessons (of at least 50 minutes) in the timetable to give teachers flexibility about when they do experiments.
	Practical activities should be varied and balanced in type.
5. Laboratory facilities and equipment	There should be sufficient equipment to make it possible for teachers to do standard practical activities expected in their specialist subject at that level.
7. Real experiments, virtual enhancements	Virtual environments and simulated experiments have a positive role to play in science education but should not be used to replace a good quality, hands-on practical.
	Digital technologies are rapidly evolving and teachers should have access to evidence about what works, and training in their use, before implementing them in their science lessons.

Appendix 4: Gatsby Benchmarks

Benchmark	Criteria
8. Investigative projects	There should be opportunities for students to do open-ended extended investigative projects in science.
10. Assessment fit for purpose	Teachers should regularly use practical activities as an opportunity to formatively assess students' understanding of science, where it is appropriate to do so.

The project also aligns with the 5 purposes of practical science highlighted in the Gatsby report:

A. To teach the principles of scientific inquiry

B. To improve understanding of theory through practical experience

C. To teach specific practical skills, such as measurement and observation, that be useful in future study or employment

D. To motivate and engage students

E. To develop higher level skills and attributes such as communication, teamwork, and perseverance