How to build a Moon Base – KS3 Lesson

Learning Objectives	Curriculum Links
The Moon is the Earth's only natural satellite. Study of the Moon started in ancient times, and it is still ongoing, with several space agencies planning moon bases as early as the 2030s.	**Physics – Space physics** Pupils should be taught about gravity force, weight = mass x gravitational field strength (g), on Earth g=10 N/kg, different on other planets and stars; gravity forces between Earth and Moon, and between Earth and Sun (qualitative only)
There are many factors that should be considered when planning a permanent Moon base, including: location, sources of power, and the logistics of building the base. Resources are limited on the Moon compared to Earth. The most viable source of power is solar power, and materials to build a base must be sourced locally.	**Chemistry – Earth and atmosphere** Pupils should be taught about the Earth as a source of limited resources and importance of recycling **Geography – The use of natural resources**
The Moon is covered in regolith, a thick layer of unconsolidated sediment (small particles of rocks and dust). Technologies are being developed to convert lunar regolith into building material. These technologies are similar to the way the rock cycle can turn sedimentary rocks into more durable igneous rocks, by melting and recrystallising the sediment.	**Chemistry – Earth and atmosphere** Pupils should be taught about the rock cycle and the formation of igneous, sedimentary and metamorphic rocks **Physics – Matter** Pupils should be taught about conservation of material and of mass, and reversibility, in melting, freezing, evaporation, sublimation, condensation, dissolving **Science – Working scientifically** Pupils should be taught to make and record observations and measurements using a range of methods for different investigations; and evaluate the reliability of methods and suggest possible improvements **Geography – Rocks, weathering and soils**

Materials needed:

- Samples: anorthosite (samples 17a, b, c), basalt (samples 18a, b, c), breccia (samples 19a, b, c), regolith simulant vials (samples 21a, b), lunar meteorite (sample 12)
- Hand lenses
- Handouts

Lesson length: 50 minutes

Lesson Plan

Slide	Geology	Teaching/Learning activity	Time
1 - 3	The Moon is the Earth's natural satellite, and it has fascinated civilisation for millennia – there are depictions of the moon in prehistoric cave paintings, ancient rock carvings and sculptures. The first telescopic observations came from Galileo in 1609, but the first physical exploration of the moon began with Luna 2, a Soviet mission in 1959. You're probably familiar with NASA's Apollo missions following shortly after, which included the first crewed Moon landing, as part of the Apollo 11 mission in 1969. For geologists, the Apollo missions were valuable because they returned Moon rocks to the Earth, which allowed us to learn a huge amount about how the Moon formed. They also allowed us to confirm that some meteorites found on Earth originally came from the Moon! Since the Apollo era, there haven't been any crewed lunar landings, but there were various spacecrafts sent into lunar orbit to study it from afar. Robotic lunar landings restarted recently, with the Chang'e missions targeting the far side of the Moon, which previous missions hadn't previously explored. Multiple space agencies and private companies are currently investigating how to build permanent moon bases that humans could survive in, which is what we're also going to do today! Things to consider when planning a moon base: - Location (safety and usefulness) - Sources of power - How to build it and using what material	*Introduce the Moon and a brief history of lunar exploration* *Pass around the lunar meteorite for students to have a look at while you talk about lunar exploration* ***Ask students what they think we need to consider when planning a Moon base?***	5 mins

4 - 8	The Moon doesn't have any fossil fuel resources because we don't think it ever had plant or animal life from which fossil fuels form. There is also no liquid water and no atmosphere, so wind and hydroelectric power are not options. The only viable option is solar power, or perhaps nuclear power (*this is actively being researched and may not actually be viable – don't bring it up unless they do). The lunar day/night cycle is 29.5 days, so each region on the Moon receives approximately 14 consecutive days of sunshine. However, its rotation axis is slightly inclined (approximately 1.5 degrees), so there are some ridges and peaks at the south pole that receive sunshine 80% of the year. This means that the base could be powered 80% of the time, which is the best option. This region being at the poles also solves the need for water, because there are ice sheets at both poles of the Moon, so the ice could be melted to provide water.	***Ask students what kind of electricity could we have on the Moon?*** *(Answer: no fossil fuels, no wind, no water => solar, or perhaps nuclear*)* ***We need solar panels where there is the most Sun. Where do they think that might be?*** *Ask them to consider the Moon's rotation and play a video to help them visualise it (Slide 8).* *Reveal south pole location where there is most sun– **what else tends to exist at the poles of a planet that might be helpful for a moon base**?* *Hint: what's the at the Earth's south pole?* *Answer: ice sheets, which could be melted to make water!)*	15 mins
9 - 11	**Basalt** = fine volcanic rock, formed when extruded lava cools down and crystallises. It is usually dark in colour, and it is a common building material. On the Moon, basalt is found in the dark areas, called *lunar maria*. **Anorthosite** = intrusive, coarsely crystalline igneous rock, light in colour. On the Moon, it is found in the lighter areas, called *highlands*. It's not as common as basalt on the Earth, but it is used for construction, nevertheless. **Breccia** = a rock made of fragments of other rocks. On the Moon, this forms when regolith and other rock fragments become compacted into and form a new rock. Breccia can be found in both	*Final consideration: how to build a moon base and what material to use.* ***Ask students what are usual houses build from?*** *The usual answers (brick, rocks, wood) are not possible because there is no wood on the moon, and we can't easily fly bricks or other building materials over to the Moon. Therefore, building material must be sourced from the Moon.* ***Give an overview of Moon rocks, where they are found and their properties.***	5 mins

	maria and highlands. Depending on how compacted it is, it can be hard or soft. **Regolith** = loose sediment (dust and rock pieces) that occurs on planets without atmospheres and asteroids. It forms through repeated meteorite impacts, and it can be quite thick (in highland regions, it can be 10-15m deep on the Moon). The material in the vials is regolith analogue (also known as a simulant), so the components are the same minerals in the same size ranges but sourced from the Earth rather than the Moon. There are two vials: one with simulant for the Moon, and one for Mars. They are similar, except for slightly different composition, colour, and grain size (Mars regolith is coarser and brown in colour). Note for teachers: regolith simulant is important for space mission preparedness, so spacecrafts can be tested on material similar to that found in space. Simulant is also used to test the mechanical and chemical properties of regolith ahead of a mission.		

12	Students should make usual rock observations: - Crystals or grains? - Size of crystals or grains - How hard is it? - Any other features **Grains:** very small (less than a few mms) piece of mineral or rock. You can tell if a rock has grains if the small pieces are visibly different to the rest of the rock. **Crystals:** individual minerals which have grown in crystal form in a rock **Mineral:** a naturally occurring substance made up of elements **Crystalline:** rock made up of crystals that interlock (fit together like puzzle pieces)	*Next, the students will decide which rocks are best for building.* ***Activity: divide students in 3 groups and give each group 3 rocks (basalt, anorthosite, breccia).*** *They should also have a look at one of the 2 regolith simulant vials.* *They must make observations and write the pros and cons of using each material for building.*	10 mins

	To help them work out if something would be a useful building material on the Moon, they could consider if something is easy to mine and easy to turn into bricks – hard rocks are difficult to mine and shape however we want without a lot of equipment.		
13-18	Technologies are being considered to turn regolith into building material, like regolith 3D printing. This would involve transporting a large 3D printer to the Moon, which takes in regolith, melts it and forms it into rock which can be shaped in any way we want. It could be shaped directly into a structure, like in ESA's 2013 study using a lightweight structure similar to the interior of a bird's bone. They propose building a regolith dome around the capsule that the astronauts landed in. Alternatively, CNSA (China National Space Administration) is considering 3D printing bricks, which would then be used to form eggshell-shaped buildings. Either way, this technology causes changes similar to those found in the rock cycle, taking in sediment, melting it, and transforming it into a more durable material once it cools down – just like how sedimentary rocks can be melted to form igneous rocks! This change in material is irreversible (although it's possible to take igneous rock and grind it down until it's sediment, it will not be the same as it was before)	***Go through each rock and discuss the pros and cons of using it for building.*** ***Have a vote*** *– which rock would they use?* *They will probably choose basalt or anorthosite, because they are harder. Having solid rock would be ideal, but it's difficult to mine without specialised equipment. What if they could only use regolith?* ***Ask students how can we make solid rock from regolith?*** *Hint: consider the rock cycle* *The rocks they chose are both volcanic, which means they were molten and recrystallised. What if there is a way to do that with regolith?* ***Briefly explain Moon 3D printing.***	10 mins

19 - 21	Right now, several space agencies are thinking about building these moon bases in the 2030s – so really, this could even happen 5 years from now! NASA's Artemis program, which the UK and European Space Agencies are involved in, is currently ongoing and training astronauts for Artemis II, due to launch next year. Artemis III aims to land astronauts on the Moon again around 2026. Meanwhile, the CNSA wants to build an International Lunar Research Station,	***Give an overview of future lunar exploration (ongoing and upcoming missions)***	5 mins

	also at the South Pole, so it's a very exciting time to be looking up at the Moon!		