Teaching material 2 (Teachers):

Topics:	Earth-Moon relationship, location factors, astronomy, remote sensing
Subjects:	Geography, Physics
Grade:	9-13
Media & Material:	Maps from Lunaserv remote sensing data, augmented reality app “Columbus Eye”, worksheet
Scope:	90 – 135 minutes
Key question:	Do the given location factors allow for human settlement on the Moon?

Competences

Subject Competences

The students...

... describe and explain the given location factors of the Moon (temperatures, composition of the Moon's atmosphere, and other location factors).

... compare the location factors of the Moon with those of Earth and draw conclusions.

... show which regions of the Moon have the highest potential for human settlement.

Methodological competences

The students...

... use satellite-based and ground-based data of the Moon and the Earth to analyze the facts.

... find a way to present more complex visualizations and working materials (graphically) and are using a combination of worksheets and Lunaserv material to discuss the content liguistically.

... experience the process of gaining knowledge by discussing their approaches and results.

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Judgmental competences

The students...

... evaluate their methodological approach to analyze location factors on the Moon and on Earth and by assessing potential locations for human settlement.

... assess how suitable the materials provided are for the work assignments and to what extent there is potential for improvement in the materials.

Executive competences

The students...

... present their work results in a relevant and technically appropriate manner.

Curriculum

This lesson focuses on the process of gaining knowledge, a process-related skill. In terms of content, it is not possible to establish direct links to all core curricula of the federal states in relation to the lunar analyses. However, there are at least some possibilities for linking to existing content areas. In physics, this refers to the astronomical component and in geography to the Earth-Moon relationship.

This unit covers many of the sub-skills of knowledge acquisition that are evident in scientific ways of thinking and working. Specific examples of how this relates to the curriculum can be found in the table below. Note, that all presented topics are implemented into the curriculum of the german federal states only.

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Subject	Geography	Physics
Topics	Location factors, Earth-Moon relationship, remote sensing	Astronomy, Earth-Moon relationship
Baden-Württemberg	9/10: Digital orientation (GIS, remote sensing), 11/12: The Earth-Moon system, processes in the atmosphere	11/12: Advanced topic area: astrophysics, cosmology
Bavaria	10: Geographical working techniques and methods 11/12: Geographical working techniques and methods	10: Astronomical world views, cosmology
Bremen	Qualification phase: Physical geography fundamentals and processes,	Qualification phase
Berlin	Introductory and qualification phase: Geosphere	Introductory phase: Movement of artificial satellites Qualification phase: Astronautics
Lower Saxony	Upper secondary level: physical-geographical factors, spatial orientation	(Upper secondary level)
North Rhine-Westphalia	Introductory and qualification phase: changing significance of location factors	Introductory phase: circular motion, gravity, and physical worldviews
Thuringia	-	11: Temperature and heat

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Didactic commentary

The teacher begins the lesson by setting a silent impulse. The students are shown a compilation of materials that they use to activate their prior knowledge and formulate their associations, ideas, and comments. The students independently identify a common and central problem that the materials point to and develop a problem statement. The collection of materials draws attention to various problems facing the population and the Earth. For example, the materials show the rise in air temperature due to climate change and images of extreme weather events, which are also to be interpreted in the context of climate change. In addition, the consumption of resources by humans and the resulting overburdening of the Earth are discussed. The image at the top right shows, for example, that the day on which the sustainably usable resources of a year are consumed is coming earlier and earlier, thus illustrating the ecological limits of our planet. Furthermore, war can also be considered as an indicator of the destruction of our planet.

The focus is on the long-term destruction and change of our home planet Earth. In the course of this, the students independently conclude that our planet will probably become uninhabitable at some point and consider possible solutions to this problem. For example, they develop ideas on how to respond to this development and how to act in the future. The students consider at least two possible solutions, which are then discussed. One solution could be to pass extreme laws that force people to act in a more environmentally conscious and sustainable manner immediately, for example to counteract climate change. Here, students can also discuss how realistic this solution is (how will people react to it?) and whether the processes are already too far advanced to be stopped (point of no return).

Another solution is the expansion or colonization of another planet. This approach also presents difficulties, as the solar system and many of its planets have not yet been fully explored. The best-studied object is Earth's Moon, which may serve as a solution to our problems and whose location factors will be examined in more detail in this lesson.

After introducing the topic of the Earth-Moon system in this manner, establishing a clear connection to the real world that reveals the relevance of studying the Moon, and allowing the students to develop their own questions or problems, we move on to the second worksheet and the first task. Here, the students are asked to compare life and living conditions on the Moon with those on Earth in a Venn diagram. The students can think in particular about the challenges, that would face us with life on the Moon.

The LUNA project, which is being developed at the EAC in Cologne, can be cited as an example to raise

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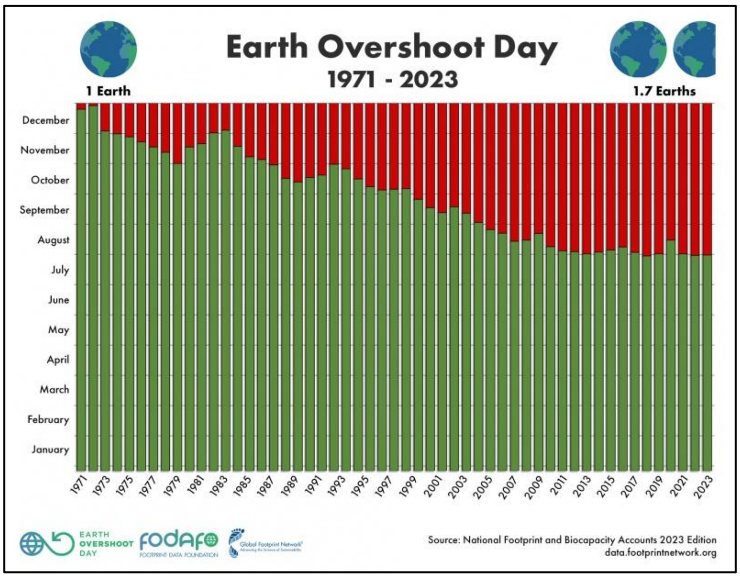
awareness and prepare for the different environmental conditions. To test technologies for operating a lunar station, moon-like conditions are being created on 1,000 square meters. The aim is to develop a freely accessible, cost-neutral test facility for surface missions. The primary goal is to develop a self-sufficient energy supply for the Moon.

Material compilation

Photo: picture alliance / ASSOCIATED PRESS | LIBKOS



Extreme weather collage (Photo: Collage dpa/Feuerwehr Riedlingen)

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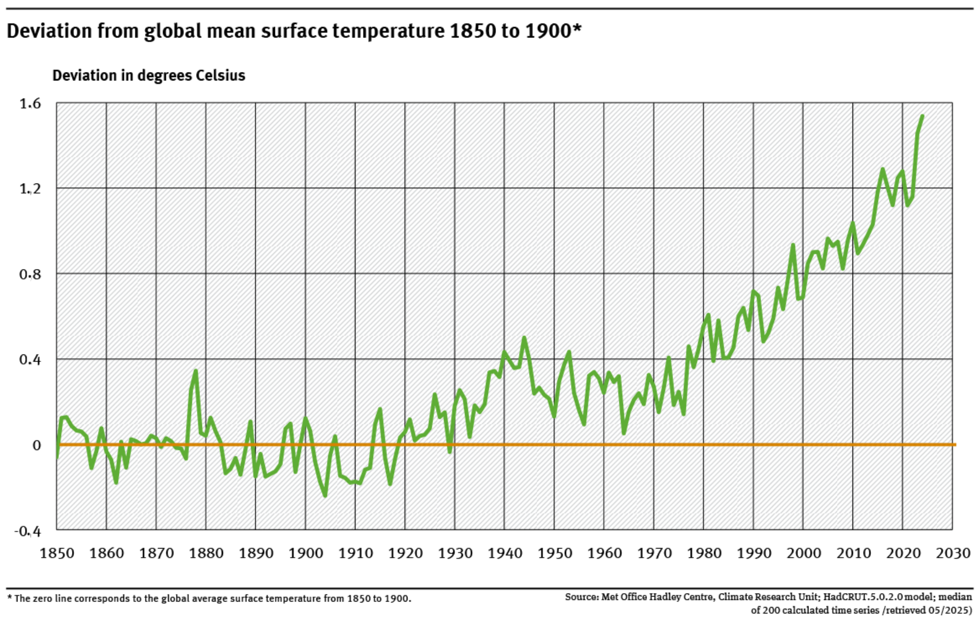

The students then carry out a location analysis or utility analysis using the think-pair-share method (starting with task 2). To do this, the students first work on the tasks individually (think). The students independently define criteria for life on the Moon and rank them according to their importance. They then exchange their thoughts with a partner (pair) and present their results to the class (share). In this way, the results are temporarily saved, and the teacher gains a better overview of the students' prior knowledge, enabling them to better observe and assess their learning progress. The aim of the lesson is for students to use their acquired knowledge to evaluate the potential of the Moon as a future place to live.

The students work on tasks to determine various key characteristics of the Moon and evaluate them using map material that can be used interactively in the augmented reality app "Columbus Eye", as well as other images and texts. The students then consider which location they think is most suitable for colonization, mark it on the map, and justify their opinion. After gaining new insights, the students reflect on the weighting of the various location factors and revise them if necessary. They exchange ideas with a partner (pair) and enter their assessments in a table. The weighting and evaluation points are multiplied and added together for each location. The highest score indicates the most suitable location. The students prepare the results so that they can be presented to the whole class. Finally, the results are presented, discussed, and confirmed in a plenary session.

As an additional task or outlook, the students can explore other long-term problems associated with permanent settlement on the Moon. Examples include the effects of microgravity, radiation exposure, and

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isolation over long periods of time. These topics are currently being researched on the ISS and have therefore not yet been fully investigated. The Moon can also be considered as a tourist destination. This could lead to a follow-up discussion about colonizing other planets, such as Mars. As Thomas Reiter, astronaut at the European Space Agency (ESA), said back in 2012: "*In my view, the Moon is a logical stopover.*"

Think-Pair-Share method

The Think-Pair-Share method alternates between individual and cooperative work phases. The method consists of three steps. In the first step (Think), students work independently on topics and tasks, which they then present or explain to their classmates in a second phase (Pair) and discuss their results. In the third phase (Share), there is a discussion in the whole class. In addition to promoting social learning, this method can also contribute to improved knowledge retention (see Bönsch, 2002). The method can be applied to topics that involve either collaborative or equal work. Accordingly, task 2 can be divided, but this is not necessary. In a high-performing class, the teacher can, for example, divide the tasks so that the students work on them collaboratively. For example, student 1 would work on task 2.2 and student 2 on task 2.3. In the second phase (pair), the students present their tasks to each other so that they can then explain and present both tasks and results in a plenary session (during the interim review). This allows the students to experience synergy effects. However, this also means that each individual has greater responsibility and there is a risk that the students will not be able to complete the tasks on their own. In this case, the problem cannot be easily solved in the partner work phase, as the partner has been working on other tasks and is unfamiliar with the other tasks.

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Lesson plan

Time	Phase	Lesson activities	Methodological-didactic Comments	Social form	Media
10 min	Introduction	The teacher provides silent input by showing the students a collection of materials. Students activate their prior knowledge, describe what they see, form associations, and evaluate given images, illustrations, and data sets.	The teacher notes the students' thoughts on the board in bullet points.	Class Discussion	Board/ Projector
5 min	Problematization	The question for the lesson will be identified.	The students independently develop a question or problem for the lesson. The question should highlight the relevance of the topic and be written down clearly. For transparency, the lesson plan is briefly presented to the students.	Class Discussion	Board
10 min	Development 1	The students record the differences and similarities between living conditions on Earth and the Moon in a Venn diagram. They then define criteria for life on the Moon and rank them in order of importance.	The prior knowledge of the individual students is activated. The students brainstorm their thoughts on a new topic and write down their ideas.	Individual	Worksheet

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10 min	Interim review	The students present their results and ideas in a plenary session.	The teacher notes the results in bullet points on the board. This interim assessment gives the teacher an overview of the students' prior knowledge and allows them to better track learning progress at the end of the lesson.	Class Discussion	Board / Projector
10 min	Development 2	The students first work out the difference between hard and soft location factors and use this to subdivide their previously established ranking list.		Individual (think)	Worksheet
5 min	Development 3	The students discuss their results and supplement or revise them if necessary.	The PA allows weaker students to be supported and helps students feel more confident when presenting their results afterwards.	Partner work (pair)	Worksheet
10 min	Interim review	The results are presented and compared in a group discussion.	The teacher has the opportunity to intervene and correct any mistakes.	Class Discussion (share)	Board / Projector
10 min	Development 4	The students explore the characteristics of the Moon. First, they work on tasks related to the topography and temperatures of the Moon's surface.	To do this, the students use images, texts, and map content that are also available in the augmented reality app "Columbus Eye."	Individual (think)	Worksheet, Interactive tool

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5 min	Development 5	The students exchange ideas with their partners again, revise their results, and prepare them for presentation to the whole class.		Partner work (pair)	Worksheet, Interactive tool
10 min	Interim review	The results are presented and compared in a plenary session.	The teacher has the opportunity to intervene and correct any mistakes.	Class Discussion (share)	Board / Projector
10 min	Development 6	The students work on tasks related to the availability of water and other resources.	To do this, the students use images, texts, and map content available in the augmented reality app "Columbus Eye"	Individual (think)	Worksheet, Interactive tool
5 min	Development 7	The students exchange ideas with their partners again, revise their results, and prepare them for presentation to the whole class.		Partner work (pair)	Worksheet, Interactive tool
10 min	Interim review	The results are presented and compared in a group discussion.	The teacher has the opportunity to intervene and correct any mistakes.	Class Discussion (share)	Board / Projector
15 min	Development 8	The students select a location they consider suitable for Moon colonization and justify their opinion.	The students answer the guiding question.	Partner work	Worksheet, Interactive tool

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15 min	Verification	The results are presented, compared, and discussed in a plenary session.	Different priorities for suitable locations can serve as a basis for discussion.	Class Discussion	Board / Projector
5-10 min	Outlook	As an addition, the class can discuss other long-term and permanent problems related to settling the moon (e.g., microgravity, radiation exposure, isolation). In addition, the Moon can be considered as a tourist destination and the colonization of other planets, such as Mars, can be discussed.	The teacher can note down the students' thoughts in bullet points.	Class Discussion	Board / Projector

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Possible solutions to the students' tasks

1. Venn diagram

2.1. Definition of hard and soft location factors:

A location factor is an economic, social, or geographical characteristic or condition that influences the attractiveness of a particular location for companies, investors, or individuals. Location factors play a decisive role in the choice of location for companies and can have a significant impact on their success.

Hard location factors are measurable, objective, and stable (such as costs, infrastructure, and availability of space). Soft location factors are more subjective and relate to quality of life (e.g., education and culture). Both types of factors should be taken into account when choosing a location.

2.1.1 Schematic diagram of location factors on the Moon

2.2. Comparison of the surface of the Moon with that of the Earth:

- The terrain near the equator on the near side of the Moon is generally flatter than the rugged lunar landscape of the South Pole region and the side facing away from Earth. Mare areas and highlands.
- Many craters and mountainous landscapes documenting bombardment by asteroids and meteorites – no protection from atmosphere or magnetic field.
- No erosion, no rain, no plate tectonics (geological activity), etc., which renew or change the surface.

2.3. Extreme temperatures and the length of the day on the Moon:

Unlike Earth, where the atmosphere stores and distributes heat to moderate temperature differences between day and night, the Moon has no such protective layer. Without an atmosphere, the Moon's surface is directly exposed to solar radiation. Another important factor is the slow rotation of the Moon. A day-night cycle on the Moon lasts just under 29.5 Earth days. During the two-week day phase, the sun heats the Moon's surface strongly, leading to extremely high temperatures. In the two-week night phase, however, there is no solar radiation, and the

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surface quickly loses heat to the cold space. The absence of an atmosphere and the limited number of molecules on the Moon's surface mean that the temperature differences between day and night occur extremely quickly.

In addition to the rapid temperature change, there are also significant temperature differences between regions on the Moon. Areas near the lunar equator can heat up and cool down more than the poles because the sun's rays are more perpendicular there.

2.4. Water availability and states of matter:

Due to the pressure on the Moon's surface, water only exists in the form of ice. The largest ice deposits are found in the permanently shaded polar regions, especially in the craters of the north and south poles. In all other regions of the Moon, the water evaporates due to the high temperatures caused by solar radiation. In order to use the Moon's water resources, the pressure would have to be artificially increased.

2.5. Resource availability and geological activity:

Water is one of the most valuable raw materials on the Moon, as it can be used as drinking water for astronauts and to produce oxygen and hydrogen for fuel.

Water ice occurs particularly in the polar regions of the Moon. Helium-3 is a potentially valuable fuel for nuclear fusion. It occurs mainly in the uppermost layer of the lunar regolith. Many other raw materials, such as iron, titanium, and mafic silicate rock, are found in greater quantities in the equatorial regions of the Moon's near side. Silicon, aluminum, and magnesium are also widespread across the entire surface of the Moon.

These parameters are particularly relevant for selecting a location on the Moon, as a balance must be struck between raw material deposits, which should be weighted accordingly.

3. Location of the lunar base:

The most important factors that determine the location of a lunar base are: **Water resources** (water is essential for drinking water, oxygen production, fuel)**, sunlight** (for energy supply, efficient solar energy)**, accessibility** (proximity to landing sites, less logistical effort)**, topography** (a flat and stable surface is important)**, communication** (good communication links, mainly on the near side of the Moon)**, scientific interests** (e.g., research into specific geological or astronomical features)**,**

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protection from radiation and other extra-lunar risks (protective mechanisms against cosmic radiation and meteorites due to the lack of an atmosphere)**, availability of resources** (geologically interesting and resource-rich areas)

Weighting: 1 = not important; 5 = very important

Site assessment: 1 = hardly applies; 5 = fully applies

Location factor	**Weight**	**Location 1**	**Location 2**	**...**	**...**
Topography					
Temperature and light					
Water					
Resources					
...					
...					
Total	-				

To compare the individual locations, the weighting and evaluation points are multiplied and then added together for each location. The location with the highest score is the most suitable.

Addition 5. Challenges for long-term life on the Moon:

Radiation, life support systems (supply of air, water, food)**, weightlessness** (muscle and bone loss)**, medical care, isolation and psychology** (mental health)**, technical challenges** (especially due to extreme temperature differences)**, communication, resources** (dependence on Earth should be minimized)**, political and financial support** (considerable financial expenditure)**, Long-term motivation** (long-term goals should be set to maintain people's motivation to live on the Moon)

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Addition 6. Weight on the Moon:

Own body weight on Earth / 6.05= Own body weight on the Moon

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