Teaching material 1 (Teacher)

Overview

Topics:	Earth Moon relationship, astronomy, remote sensing
Subjects:	Geography, Physics (Astronomy)
Grade:	9-13
Media & Materials:	Maps from Lunaserv remote sensing data, augmented reality app "Columbus Eye", worksheet
Scope:	At least 90 min
Key question:	What is the geological composition of the Earth and the Moon and what does this tell us about the formation of the Moon?

Competences

Subject competences

The students...

... describe the geological composition of the Earth's mantle and the moon.

... recognize and name the similarities between the composition of the Earth's mantle and the moon.

... describe the collision theory involving the protoplanet "Theia" and Earth.

... analyze the previously identified connections and derive hypotheses about the formation of the moon.

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 determining the composition of the Earth's mantle and the Moon and to formulate hypotheses about the formation of the Moon.
... 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 Germany in relation to lunar analysis. However, there are at least some possibilities for linking to existing content areas. In physics, this relates to the astronomical component and in geography to the Earth-Moon relationship, geology, remote sensing, and location factors.

This unit covers many sub-skills of knowledge acquisition that are evident in scientific ways of thinking and working. Specific examples of curriculum relevance can be found in the table below. Note, that all examples are related to the curriculum in Germany.

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Subject	Geography	Physics
Topics	Geology, Earth-Moon relationship, remote sensing, location factors	Astronomy, Earth-Moon relationship
Baden-Württemberg	9/10: Digital orientation (GIS, remote sensing), endogenous and exogenous processes 11/12: The Earth-Moon system, spheres in the Earth-Moon system	9/10: Mechanics and dynamics 11/12: Gravitational fields, advanced topics in astrophysics, cosmology
Bavaria	10: Geographical working techniques and methods 11/12: Geographical working techniques and methods, geological processes (for alternative geology curriculum)	10: Astronomical world views, Newtonian mechanics (gravitation), cosmology
Bremen	Qualification phase: Physical geography fundamentals and processes	Qualification phase
Berlin	Qualification phase: Geosphere, endogenous processes	Introductory phase: Earth's rotation (Moon), movement of artificial satellites, gravity Qualification phase: Gravity, tides, space travel
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: Gravitation (weight, tides, planetary motion), circular motion 12: Gravity

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Didactic commentary

The teacher introduces the topic by asking the students to consider and discuss whether the moon or the Earth is older and how these two celestial bodies were formed. They also discuss how scientists can obtain information about the early Earth when it is constantly being recycled by geological processes. If there is a clear controversy among the opinions, this is used to raise questions and as an opportunity to confront the students with different theories about the formation of the moon.

The students are then given a worksheet listing four well-known theories of the moon's formation: the collision theory, the capture theory, the co-formation theory, and the fission theory. In addition, the teacher makes it clear to them that there are a number of other theories and considerations in science regarding the formation of the Earth and the moon. The students then discuss in a plenary session which of the theories they consider most plausible and why they hold this opinion. The students formulate hypotheses on how they can find out which of the two theories is the scientifically accepted or evident theory. In addition, the question of what the origin of the moon tells us about the Earth should be clarified, thus highlighting the relevance of the topic. In this way, the principle of controversy (according to the Beutelsbach Consensus) is used to construct an approach to the didactic principle of science orientation. Students thus learn a critical and reflective approach to science. In this way, the students are assigned a control function by applying scientific methods of knowledge acquisition for learning and problem solving and by rehearsing scientific work.

In order to answer the question about the origin of the moon, the students once again look at the various theories of origin individually and compare them with each other. They then work independently on tasks 2.1 to 2.4. After the first two subtasks, there is an initial interim assessment. After subtask 2.4, there is another interim assessment of the results in a plenary session. While working on the tasks, the students answer various questions with the help of texts, illustrations, videos, and maps (which can be viewed and used interactively in the augmented reality app "Columbus Eye") and thus collect possible evidence/data that could explain the theories described above. In addition, the four potential theories of origin are also visually implemented in the AR app.

After the results of task 2 have been discussed, the students come together in small groups to design a model-evidence link diagram (MEL) using their evidence. In this diagram, they should decide which evidence they consider to be most meaningful, and which supports the theories to what extent. The scale ranges from "the evidence strongly supports the theory" to "there is no connection between the evidence and the theory."

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They also justify their decisions and assignments. Finally, they evaluate their results by assigning a plausibility rating between one and ten to both models/theories.

Afterwards, students can test their thoughts on the plausibility of the formation theories again in the AR app using the built-in quiz. If they answer correctly, they will be taken to the NASA educational video presenting the collision theory. The video can also be viewed here: https://www.youtube.com/watch?v=kRlhlCWplqk

In a final review phase, the results and difficulties as well as the potential for conflict are presented, discussed, and confirmed in a plenary session. The additional tasks focus on the questions of where the remains of the protoplanet might have disappeared to and what consequences the formation of the Moon had for Earth. The questions can also be taken up as an outlook in relation to the limited possibilities for verification and technical development.

Optional: Learning pace duet / bus stop meeting point

If time permits, the cooperative method of learning duets can also be integrated. To do this, a meeting point is agreed at the beginning of the lesson, where students can go after completing the tasks or if they encounter difficulties. This method allows students to compare their results with a partner before the plenary discussion and help each other with any difficulties. On the one hand, it gives all students the opportunity to get together with other students who have similar learning and working speeds and compare their results. On the other hand, it can also be used to enable weaker students to receive support from stronger students. This method can therefore also serve as a question or aid. Anyone who has a question goes to the agreed meeting point, where students who have already finished the tasks can also go to offer their help and support to weaker students. Faster or more capable students can thus either team up with weaker or slower students and help them with the tasks, or – if there is no need at that moment – work on the additional tasks to deepen their knowledge. In this way, differentiation takes place automatically.

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Lesson plan

Time	Phase	Lesson activities	Methodological-didactic Comments	Social form	Media
10 min	Introduction	The teacher provides impulse by asking questions and allowing the students to discuss them. This draws on the students' prior knowledge.	The teacher notes the students' thoughts on the board in bullet points. A problem is developed based on the students' potentially controversial attitudes and levels of knowledge (controversity principle).	Class Discussion	Board
5 min	Problematization	The question for the lesson will be identified.	The question should be written down clearly. For transparency, the lesson plan is briefly presented to the students.	Class Discussion	Board

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20 min	Development 1	The students compare the different theories, then in task 2 they develop different proofs/evidences for the theories of origin.	The students take notes on all tasks and try to work on them independently first.	Individual or partner work if necessary	Worksheet, Interactive tool
15 - 20 min	Interim review	The results are presented and compared in a group discussion.	The teacher has the opportunity to intervene and correct any mistakes. If necessary, an initial interim check can be carried out earlier. This can be done, for example, after half of the subtasks have been completed.	Class Discussion	Beamer
15 min	Development 2	The students assess the plausibility of the various proofs and evaluate them for the different theories.	The results are clearly presented in the form of a model-evidence link diagram.	Group work	Worksheet
15 min	Verification	The results are presented, compared, and discussed in a plenary session.	The teacher has the opportunity to intervene and correct any mistakes.	Class Discussion	Beamer

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5 min	Outlook	Considering the additional tasks, discuss how the theories of origin can be scientifically validated, particularly in light of advancing technological progress.		Class Discussion	

Possible solutions to the students' tasks

1. The four theories of formation

2.1. Comparison of the near and the far side of the moon

2.2. Comparison of the density and internal structure of the Earth and the Moon:

Overall, the moon has a lower average density than Earth. This is due to the moon's iron core, which is very small in relation to its total diameter. The crust and mantle of both bodies have a very similar density. This supports the theory of a collision between two planets. Otherwise, the moon's core would have to be larger (and/or Earth's core smaller).

2.3. Comparison of the geological composition of the Earth and the Moon:

A similar geological composition of the mantle and crust can be observed. In both cases, oxygen and silicon make up a large proportion of the crust and mantle. It can therefore be assumed that the Moon was formed from material ejected from the outer layers of the Earth during an impact.

Of course, the conditions at Tranquility Base do not correspond to the global conditions on the Moon. Therefore, further in situ measurements, distributed globally across the Moon, are of utmost importance in order to better validate the data obtained from remote sensing. The new age determination shows that the moon was formed at a time when there were already planets in our solar system, such as Mars. It is therefore likely that the moon was formed by the collision between planets. Collisions between planets were a common occurrence in the early history of our solar system.

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2.4. Development of the distance between the Moon and Earth:

A gigantic impact could have caused the Earth to spin very quickly at that time. At that time, the Earth rotated much faster than it does today, and the Moon was also closer to Earth. Both of these factors point to the collision theory.

Addition 7. Hypothesis about where the remainders of the protoplanet could have disappeared to:
The remainders of Theia are probably hidden inside the Earth. However, we cannot yet verify this hypothesis due to technical limitations. Only volcanism offers any hope of answers, as volcanic eruptions transport deep material from the Earth's mantle to the surface, where we can then examine and analyze the rock.

Addition 8. Which impacts did the formation of the Moon have for Earth:

- ➔ The Earth has a robust iron core because it absorbed the core of Theia during the collision. This core is responsible for the magnetic field, which acts as a protective shield against cosmic radiation from space, for example.
- ➔ The Earth's axis of rotation was initially the same as its orbital axis but is now tilted. According to the collision theory, this can also be explained by the collision with protoplanet Theia.
- ➔ Tides

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