



## ***Terraforming the Solar System – VEGA Teaching Scenario***

**Topic:** To understand what criteria planets must meet to support life, and how difficult it is to achieve life-sustaining conditions on planets other than Earth.

**Subject(s):** Physics / Astronomy / English

**Age / Grade:** 11+ / grade 5+

### **Short description of the VR game in this scenario:**

[Universe Sandbox](#) is a space simulator that merges real-time gravity, climate, collision, and material interactions to reveal the beauty of our universe and the fragility of our planet. Includes VR support for HTC Vive, Oculus Rift+Touch, and Windows Mixed Reality.

### **Introduction to the scenario**

In this scenario students learn more about our Solar System. By attempting to terraform - i.e. make more Earth-like and habitable - three planets in our system, students learn which planetary properties are responsible for habitability. This assignment is difficult, and it is quite possible that no student will succeed without assistance. Because of this, this lesson also includes step-by-step instructions on how to achieve at least a 30% chance of life on Mars in Universe Sandbox. Rather than approaching this complicated subject as an assignment that has to be successfully completed, it is best to let students make several attempts at terraforming and then provide more detailed instructions during the second lesson on how to terraform Mars.

## **Learning outcomes:**

The students are able to:

- to reflect on what they already know about their solar system and how Mars, Venus, Jupiter and Earth differ from one another
- to understand how location in the Solar System influences the planets
- to see how complex and sensitive planetary bodies and their surfaces are
- name important preconditions that are required for life
- review earlier concepts such as the Goldilocks zone

## **A selection of learning outcomes from the Finnish Curriculum**

- M1 arouse and maintain the student's interest in the environment and the teaching of environmental science and help the student to realize that all subject areas in environmental science are important for him
- M2 guide and encourage the student to set goals for their studies and to work long-term to achieve them and to analyze their knowledge in environmental science
- M3 support the student to develop environmental awareness and to act and influence in their immediate environment and in different contexts to promote sustainable development and to appreciate the importance of sustainable development for themselves and the world
- M4 encourage the student to formulate questions on different subject areas and to use them as a starting point for investigations and other activities
- M5 help the student to plan and carry out small investigations, make observations and measurements in diverse learning environments with the help of different senses and investigation and measurement tools
- M6 help the student to see the connection between cause and effect, draw conclusions based on the results and present their results and research in different ways
- M13 guide the student to understand, use and create different models with the help of which one can interpret and explain man, the environment and related phenomena
- M15 guide the student to investigate nature , identify organisms and habitats, think ecologically and help the student to understand human structure, life functions and development

- M19 guide the student to understand the areas of health, the importance of healthy habits and the course of life, the individual growth and development in childhood and adolescence and encourage the student to practice and apply their knowledge on health in everyday life

### Formative assessment

#### **Number of students: Duration (estimated time/number of lessons):**

- 20 students (4 students/group)
- 2 lessons á 45 min

#### **Prerequisites (necessary materials and online resources):**

- Computers with internet connection and Universe Sandbox downloaded on a STEAM account
- VR glasses with the application installed on a gaming computer (Valve Index, Oculus Rift or some other VR Goggles connected to STEAM) **(optional but highly recommended)**
- Check that the internet is working
- Information about the topic to mediate to the students (videos, pictures, Educational tools etc.)

### **Before the program begins (preparatory work for teacher):**

- Search and collect information and material about the topic
- get properly acquainted with the app Universe Sandbox and the demo version on computer
- Prepare and collect all things needed for the scenario
- Learn how basic functions work and how you use the controllers (make a manual for the controllers if the students haven't used them before)
- Create an assignment in Google classroom with project description and goals (the same task for two lessons)

All material the students need is included in the assignment

- Divide students into groups of up to four students

### **The main part of the scenario (number of lessons):**

#### **Part one (one lesson 1 x 45 min)**

- The teacher divides the students into small groups (up to 4 per group). Each group needs access to their own computer with Universe Sandbox.
- This lesson has the students thinking about what makes **Earth perfect for life** and what other planets in our Solar System - namely **Mars, Venus** and **Jupiter** - are missing.
- Students learn about the concept of terraforming.
- Students attempt to terraform Mars and increase its life likelihood up to 30% (or more). This is very difficult and will likely require several attempts!

1. Divide the students into small groups, each with their own computer with Universe Sandbox.
2. Go through the theory below and/or your own notes on the topic with the students.
  - Terraforming is the hypothetical process of deliberately changing a planet, moon or star to become more Earth-like
  - Current technology is not capable of actually terraforming any planet in our Solar System
  - There are several requirements for a planet or moon to be a candidate for terraforming in the future:
    - sufficient mass and size to enable gravity that is capable of supporting an atmosphere as oxygen is critical for life
    - sufficient energy
    - sufficient water
    - a good temperature within the **Goldilocks zone**
3. Student discussion: Why is Earth perfect for life? Have the students discuss this amongst their group before sharing their answers with the class. Some expected observations:
  - “It is the **right distance from the Sun**, it is protected from harmful solar radiation by its **magnetic field**, it is kept warm by **an insulating atmosphere**, and it has the right **chemical ingredients** for life, including water and carbon.” - [source](#), emphasis added
4. Terraforming Mars: for the rest of the lesson, students attempt to maximize **Earth similarity** and **life likelihood** on Mars. Reaching 50% and 30%, respectively, are enough! Assist the students but also let them experiment when trying to terraform Mars. Remind them of the conditions that make Earth especially habitable.

## NOTES + HINTS

**Take notes:** Terraforming is difficult. As students try terraforming, they may wish to write down the approaches they take. This can help them learn from their mistakes and try different techniques.

**Accidents happen:** Maybe a student will delete Mars (or blow it up). If this happens, simply reload our Solar System on that computer. Terraforming is a quick process in Universe Sandbox and can quickly go catastrophically wrong. If it happens, simply restart.

**Reaching the Goldilocks zone:** Want to give a good hint for the students? How about placing Mars where Earth is? This can be done by first deleting Earth and then setting Mars' location as **1 AU** (AU = measurement of distance, 1 AU = Earth's distance from the Sun). Do note that this will heavily alter Mars' orbit as well, but may still help with the terraforming.

**Hints:** Mars lacks a magnetosphere and has an extremely thin atmosphere, which serve to make the existence of life difficult. Atmospheric pressure and a stable temperature are needed before Mars can begin to support life.

## Part two (one lesson 1 x 45 min)

- Students get to terraform Mars with step-by-step instructions.
  - Students further experiment with terraforming by attempting to terraform **Venus** and **Jupiter** - both a greater challenge than Mars.
  - Students discuss their experiences with terraforming in Universe Sandbox and the challenges they faced.
1. What challenges did the students face? Have a brief discussion with the teams on what kind of challenges they faced while terraforming Mars.
  2. Terraforming with instructions. Now, especially if groups have not succeeded in reaching 50% Earth similarity and 30% life likelihood with Mars, they can do so by following the instructions below:
    - a. Add water to Mars (either by launching a planetary body at Mars with significant water mass, such as **Europa**, or by altering Mars' composition)
    - b. Set **Surface Pressure** to 1 atm
    - c. Set **Atmosphere Mass** to 1 earth
    - d. Set **Magnetic Field Strength** to 0.317 Gauss
    - e. Set **Magnetic Pole Angle** to 12 degrees
    - f. Set **Average Albedo** to 0.75
    - g. Set **Pericenter Distance** and **Apocenter Distance** to 1.47 AU

If these instructions are followed to the letter, Mars should now reach Earth similarity 50% (or more) and life likelihood 30% (or more).

- Do students understand these measurements?
- Ask students. Can they explain what kind of change each step is? Why does it help to terraform Mars?

3. Terraforming **Venus** and **Jupiter**. Have the students attempt to terraform Venus and/or Jupiter (their choice). Leave enough time at the end of the lesson for students to discuss their attempts. Terraforming Venus and Jupiter is even more difficult than Mars, and it is likely that no group will succeed.
4. DEBRIEFING - questions for each student individually
  - Why aren't NASA and other institutions terraforming any planet yet? A: It is not possible with current technology, even if resources were otherwise limitless.
  - In your own words, explain what the terms atmospheric mass, surface pressure and magnetic field strength mean.
    - Atmospheric mass: Mass of the atmosphere, the layer of gasses that envelop a planet.
    - Surface pressure: Pressure within the atmosphere.
    - Magnetic field strength: How powerful the magnetic field of the planet is, i.e. the area where a magnetic force acts.
  - Why is Earth especially suited to life? A: Due to its atmosphere, magnetic field, location, composition and availability of water.

#### NOTES + HINTS

**Venus is too hot.** Moving Venus away to take Earth's place (go ahead and delete Earth to do this) can greatly ease its terraforming.

**Terraforming Jupiter is impossible.** Jupiter is not in the habitable zone, has no oxygen, and its enormous atmosphere of gaseous and liquid hydrogen would destroy any spacecraft before it could even land. Jupiter's size results in extremely powerful gravity that crushes anything human-made (including [the Galileo probe in 1995, after going only 75 miles below the clouds](#)).



## Summative assessment:

Grades 5-10	5	6	7	8	9	10
Activity and engagement	The student has had challenges to get the task finished. The student hasn't shown signs of engagement neither at school nor at home.	The student has only occasionally shown interest in the work and has had difficulty finding motivation.	The student has mostly shown interest in the work both at home and at school.	The student has shown interest and commitment to the work both at home and at school.	The student has shown great interest and commitment both in lessons and at home.	The student has shown great interest, responsibility and commitment both in lessons and at home.
The overall picture of the work when completed.	The student misses several parts of his work and several points are not checked in the list.	The student lacks several parts of the checklist in his work.	The student lacks certain parts of the checklist, but it is largely complete.	The student has done all the parts on the checklist.	The student has done all the parts on the checklist and you can see that the student has made an effort to include all the parts.	The student has done every single part on the checklist and it can be seen that the student has processed the content.
Images and captions	The student lacks pictures.	The student has few pictures and no captions.	The student has pictures but no captions.	The student has pictures with accompanying text.	The student has several pictures and descriptive captions.	The student has versatile pictures and descriptive and explanatory text.

<p>Showing responsibility for the completion of the work. Cooperation and peer response</p>	<p>The student had difficulty cooperating with his group and did not listen to his classmates. The student did not give a peer response and did not take into account what the group gave in response.</p>	<p>The student had some difficulties in cooperating with his group and listening to his classmates. The student gave peer feedback without following the instructions. The student did not take into account the response given by the group.</p>	<p>The student mostly cooperated well with his group. The student received and gave feedback from his group almost always according to the instructions. The response was mostly constructive.</p>	<p>The student showed responsibility and mostly a good ability for cooperation. The student received and gave feedback from his group. The response was constructive.</p>	<p>The student showed evidence of good responsibility and a good ability for cooperation. The student gave a versatile response and took the response he / she received from his / her group into account.</p>	<p>The student showed evidence of excellent responsibility and an excellent ability for cooperation. The student made an effort to formulate himself in a constructive and valuable way for the task in order to help his group further in his work. The student received a response from his group and took it into account in his own work.</p>
<p>Skills</p>	<p>The student shows obvious shortcomings in the understanding of the subject.</p>	<p>The student shows some shortcomings in the understanding of the subject.</p>	<p>The student shows evidence of a certain understanding and some learned knowledge of the subject. .</p>	<p>The student shows evidence of a good understanding and has assimilated the most important content in the subject.</p>	<p>The student shows an excellent understanding and has assimilated the most important content in the subject but lacks some knowledge.</p>	<p>The student shows evidence of an excellent understanding and fully masters the content.</p>

Language learning/English	The student has big difficulties in learning the English words.	The student struggles with and has some challenges with the English words.	The student knows the most important concepts and words in English.	The student shows evidence of understanding most parts In English.	The student has a good understanding and has learned most of the concepts and knows all the words in English.	The student masters all concepts and words in English.
The VR part and the app use	The student presents obvious difficulties in understanding how the Universe Sandbox app works. Shows a lack of interest and is careless in the use of equipment needed.	The student presents some difficulties in understanding how the Universe Sandbox app works. Trying to follow the instructions, but can not keep the interest up all the time. The student is sometimes careless in the use of equipment needed.	The student understands the main features of how the Universe Sandbox app works. Mostly follows the instructions, but sometimes lacks perseverance. Is usually careful with the equipment.	The student shows a good understanding of how the Universe Sandbox app works. The student always follows the teacher's instructions and is careful with equipment.	The student shows an excellent understanding of how the Universe Sandbox app works. Always follows the teacher's instructions and is very careful with the equipment.	The student masters the use of the Universe Sandbox app. Always follow the teacher's instructions and help their classmates. Always be careful with technology.