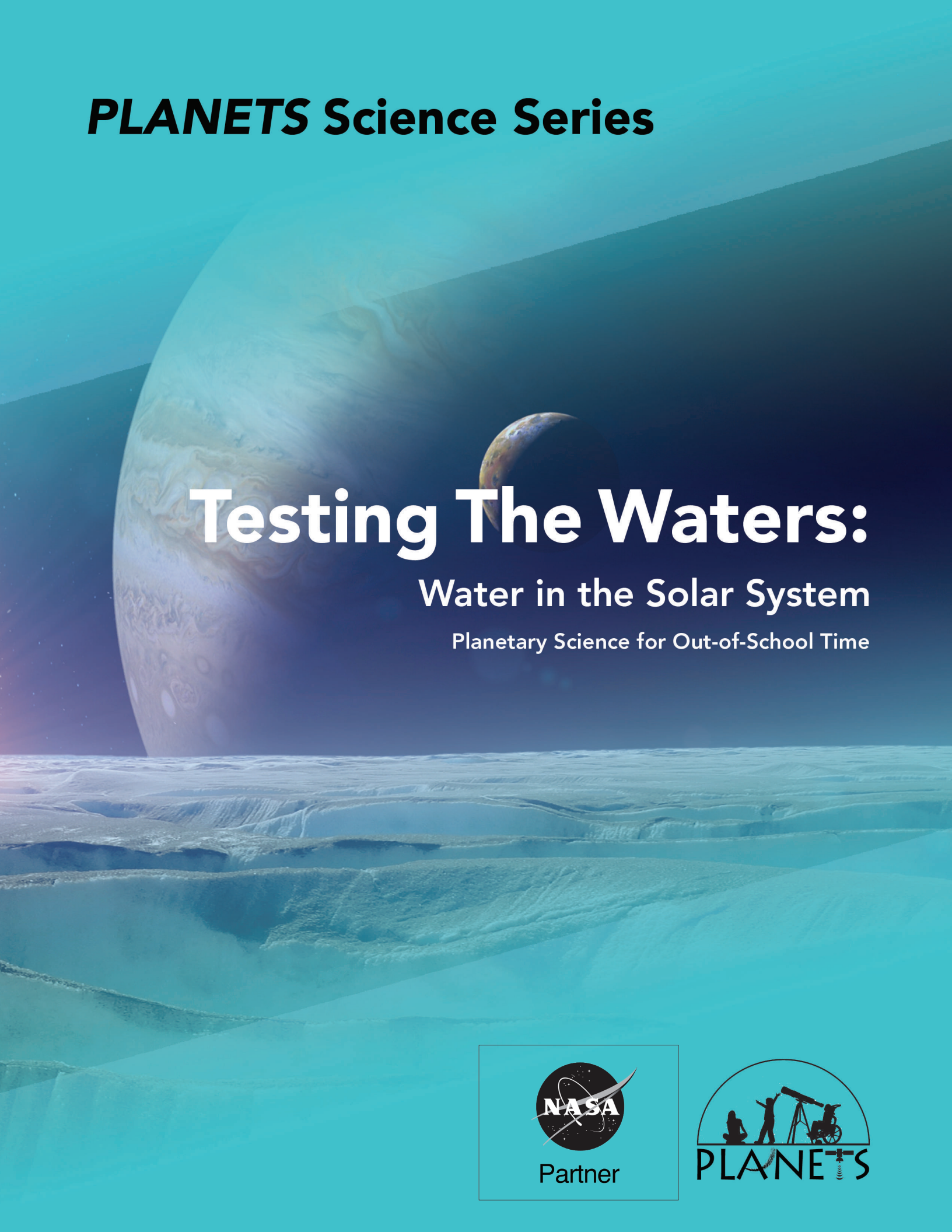
PLANETS Science Series



Testing The Waters:

Water in the Solar System

Planetary Science for Out-of-School Time

NASA Partner

PLANETS

PLANETS

PLANETS (Planetary Learning that Advances the Nexus of Engineering, Technology, and Science) is a partnership for the development and dissemination of NASA out-of-school time curricular and educator resource modules that integrate planetary science, technology, and engineering, particularly with underrepresented audiences.

This material is based upon work supported by NASA under cooperative agreement award number NNX16AC53A. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Aeronautics and Space Administration (NASA).

NAU NORTHERN ARIZONA UNIVERSITY
Center for Science Teaching and Learning

EiE

USGS
science for a changing world

NAU Collaborators:
Haylee Archer Graduate student
Nadine Barlow Professor, Department of Physics and Astronomy
Courtney Barnes Graduate student
Christopher Benson Graduate student
Nena Bloom Evaluation Coordinator and Researcher
Joëlle Clark Principal Investigator
Vanessa Fitz-Kesler Professional Development Associate
Maegan Foltz Undergraduate student
Dane Henderson Graduate student
Anne Hamlin Professional Development Coordinator
Kenric Kesler Professional Development Coordinator
Lori Pigue Graduate Research Assistant, Department of Physics and Astronomy
Jayna Powers Graduate student, Department of Physics and Astronomy
Elisabeth Roberts Evaluation Coordinator and Researcher
Lori Rubino-Hare Professional Development Coordinator
Sean Ryan Professional Development Coordinator
Brandon VanBibber Undergraduate student

PLANETS

USGS Collaborators:
Ryan Anderson Research Scientist
Lauren Edgar Research Scientist
Tenielle Gaither Research Scientist
Moses Milazzo Research Scientist now with Other Orb LLC
M. Elise Rumph Research Scientist
Greg Vaughan Research Scientist

Museum of Science – Boston Collaborators:
Christine Cunningham now with Penn State University
Martha Davis Director of Curriculum Development
Christine Gentry Research & Evaluation Analyst
Mary Eileen McDonnell Curriculum Developer
Natacha Meyer Curriculum Development, Manager
Bekka Nolan Curriculum Developer
Christopher San Antonio-Tunis Research & Evaluation Manager
Kate Sokol Senior Curriculum Developer

***PLANETS* Evaluation:**
Carol Haden Magnolia Consulting

Other Collaborators:
Mindy Bell Flagstaff STEM City
Mansel Nelson Institute for Tribal Environmental Professionals
Courtney Sullivan Arizona Center for Afterschool Excellence

Testing The Waters:

Water in the Solar System

Planetary Science for Out-of-School Time

EDUCATOR *GUIDE*

EDUCATOR *GUIDE*

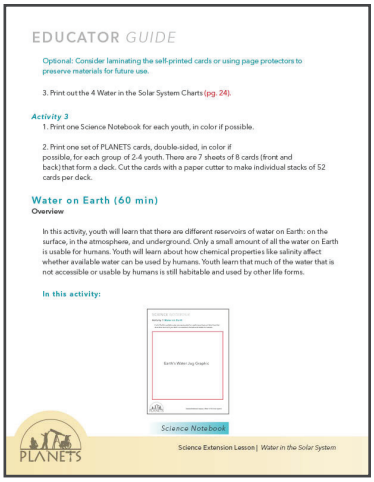
Table of Contents

About the *PLANETS* Science Series

The PLANETS Science Series supports youth exploration in the field of planetary science, by exploring the different reservoirs of water in the solar system and how accessible and usable they are for humans or habitable they are for life. This unit can be done independently, but is designed to complement the PLANETS Engineering Everywhere "Testing the Waters: Engineering a Water Reuse Process" activities, available at the link below:

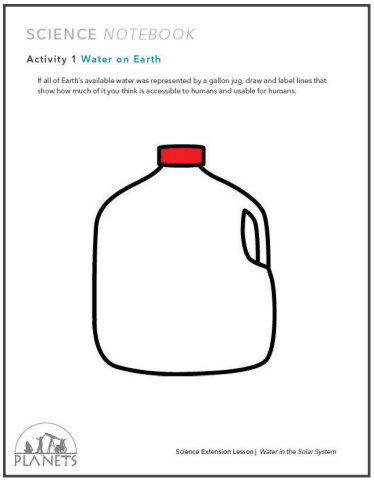
https://planets-stem.org/water-in-extreme-environments/

This PLANETS Science Series unit has several parts. All of the available materials can be downloaded from the PLANETS website.



Educator Guide

PLANETS Cards



Science Notebook

Learning Objectives

In the PLANETS Science Series: Water in the Solar System, youth will be challenged to answer the following guiding question: Where, and how accessible, usable, and habitable, is water in the solar system?

- Youth will learn where water is found on Earth and elsewhere in the solar system.
- Youth will learn about different reservoirs of water on planetary bodies and the factors that affect whether water is usable by humans or habitable for other life.
- Youth will explore evidence for water in different forms on different planetary bodies.
- Youth will consider accessibility, usability, and habitability in arguing which planetary body they want to explore.

Connections to Standards

The activities included in this unit support the teaching of multiple standards, including:

Next Generation Science Standards

MS-ESS1-3 Analyze and interpret data to determine scale properties of objects in the solar system.

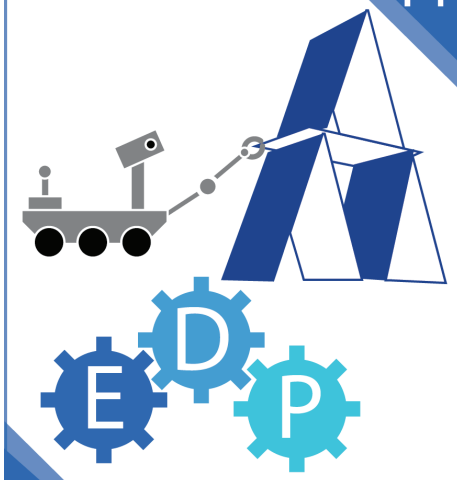
MS-ESS2-2 Describe and graph the amounts of salt water and fresh water in various reservoirs to provide evidence about the distribution of water on Earth.

MS-ETS1-3 Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

Learning Progression - Prep Activities

These activities introduce youth to engineering, an engineering design process (EDP), and the curricula's definition of technology. A video sets the context for the unit and demonstrates how engineers design process technologies that reuse water in extreme environments.

P1



What is Engineering?
Teamwork & Tower

Purpose

Youth engage in an engineering design challenge using an Engineering Design Process (EDP), criteria, and constraints.

Key Take Away

We are engineers.

Science Reflection

Today we used an EDP to solve problems with criteria and constraints.

P2

A	B	C	D
10	10	10	10
20	20	20	20
30	30	30	30

What is Technology?
Trivia & Context Video

Purpose

Youth consider the definition of technology as any thing or process humans (engineers) design to solve a problem. The Special Report Video sets the context for the entire unit.

Key Take Away

Processes designed by humans to solve problems are technologies.

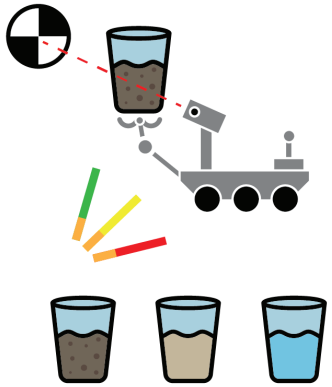
Science Reflection

Today we investigated how engineers design water reuse technologies in places where water is scarce.

Learning Progression - Engineering

In these activities, youth investigate the contaminants, filter materials, and potential uses for filtered greywater for designing their own water reuse process in Activities 4 & 5.

A1



A Grey Area
Water Samples & Quality Tests

Purpose

Youth test the quality of and categorize model water samples using real tools.

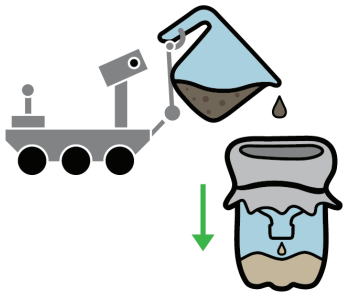
Key Take Away

We can test water quality and categorize it as pure, grey, or waste water.

Science Reflection

Today we investigated common household water contaminants and categorized model sample qualities as pure water, waste water, or grey water based on the contaminants we found.

A2



Investigating Filters
Filter Water Samples

Purpose

Youth explore how different water filter materials reduce contaminants.

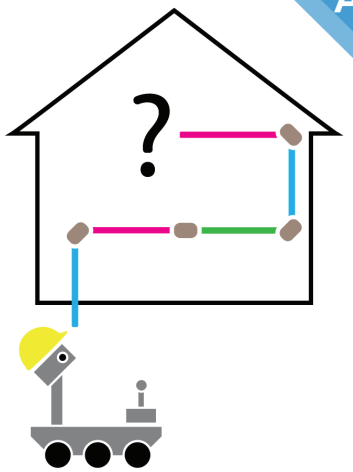
Key Take Away

We can improve water quality with filters.

Science Reflection

Today we investigated different materials to see how well they removed or reduced different water contaminants.

A3



Order Up!
Design a Water Reuse System

Purpose

Youth apply what they learned in Activities 1 & 2 to improve water quality at least one level so it can be reused for a different purpose.

Key Take Away

When water is limited, it can be filtered to remove contaminants/improve quality so it can be reused for different purposes.

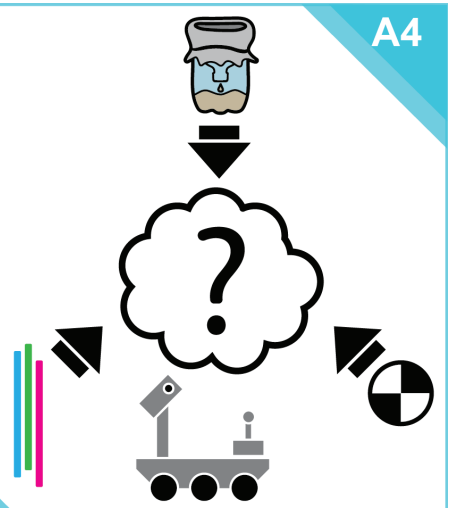
Science Reflection

Today we engineered a process to filter a limited amount of water so it could be reused for different purposes.

Learning Progression - Engineering

In these activities, youth apply what they learned in Activities 1-3 to design, improve, and share their water reuse process.

A4



Create a Process
Plan, Create, Test

Purpose

Youth apply what they learned in prior activities to design and test a water reuse process using filter materials and home piping reconfiguration.

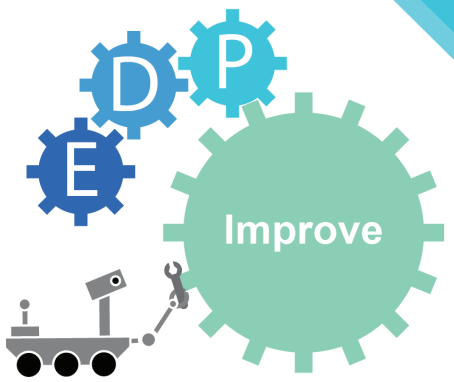
Key Take Away

We can engineer a process to improve water quality so it can be reused for other purposes.

Science Reflection

Today we used data from prior investigations to imagine, create and test a water reuse process for an extreme environment where water is scarce.

A5



Improve
Improve a Process

Purpose

Youth improve their process to better meet the criteria of their extreme environment.

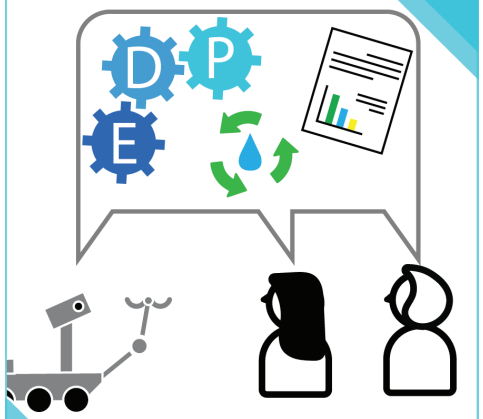
Key Take Away

We can improve technologies we have designed.

Science Reflection

Today we improved our water reuse process. Not getting it the first time helps make technology better.

A6



Engineering Showcase
Communicate Results

Purpose

Youth prepare presentations to communicate their water reuse process to others.

Key Take Away

We can communicate how we designed our water reuse process using an EDP.

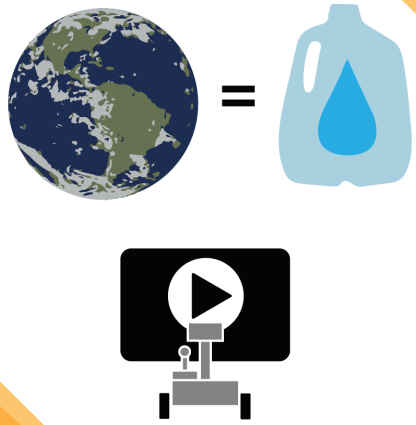
Science Reflection

Today we communicated our water reuse process and how we used an EDP to design it.

Learning Progression - Science

In these activities, youth explore how much, how accessible, and how usable water is on earth and elsewhere in our solar system. Youth also consider if water is potentially habitable on other planetary bodies. Youth also propose a planetary body to explore based on evidence of water.

S1



Earth's Water
Experiment & Videos

Purpose

Youth explore the concept of water availability, accessibility, and usability on earth.

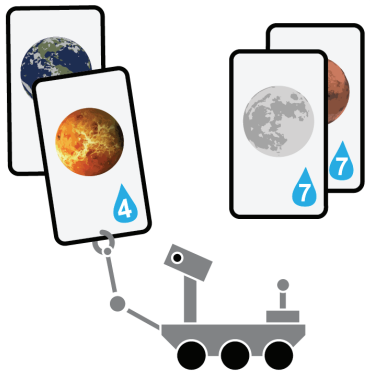
Key Take Away

Water is abundant on earth, however humans can access and use only a tiny fraction of the water. Other organisms can access and use water in ways that humans cannot.

Science Reflection

Today we investigated how various factors can make earth's water reservoirs inaccessible or unusable for humans but other organisms can access and use water in ways humans cannot.

S2



Water in the Solar System
PLANETS cards

Purpose

Youth explore where water is available in the solar system and begin to consider its accessibility and usability.

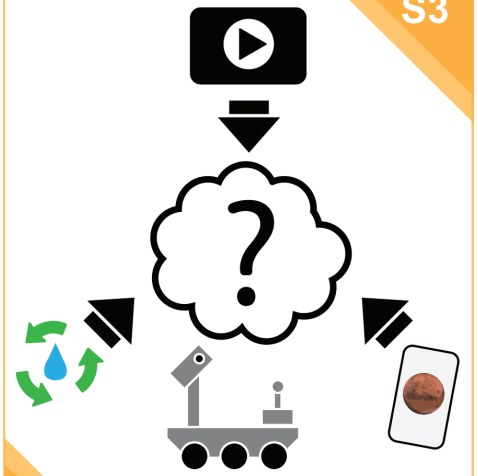
Key Take Away

Water is abundant in the solar system and exists in similar reserviors and phases as earth.

Science Reflection

Today we learned that water elsewhere in the solar system exists in similar reservoirs to earth and have similar accessibility and usability considerations.

S3



Exploration Potential
Choose a Water Reservoir & Share

Purpose

Youth propose a planetary body to explore based on the availability, accessibility and usability of water and present their choice.

Key Take Away

We can use what we learned about earth's water and evidence of water in the solar system to make an argument about what to explore.

Science Reflection

Today we explored how we can use data about water from elsewhere in the solar system to make recommendations for future exploration.

Unit Overview

In this unit, youth will learn:

- There are physical and chemical properties that determine whether water is usable by humans or habitable for life.
- The Earth has a lot of water that is found in different reservoirs: the surface, the atmosphere, and underground.
- Only a small amount of all the water on Earth is usable to humans.
- There is a lot of water in the solar system, and most of this water is found among the outer planets, farther away from the Sun than the Earth.

In this unit, youth will learn about where water is found in the solar system and whether it is likely it is to be accessible, usable, or habitable. This builds on the concepts of water reuse for extreme environments like interplanetary space and other planetary bodies in the Engineering Everywhere unit, Testing the Waters: Engineering a Water Reuse System. Youth will also explore where and what form water takes in the solar system (e.g., ice vs. liquid water). In the final activity, youth will identify potential water sources in planetary bodies for the potential for primitive life or use by human astronauts or future colonies.

In Activity 1, "Water accessibility and usability on the Earth," youth learn how the amount of available water on earth compares to the amount of usable water on Earth.

Activity 1 Guiding Questions

- How much of Earth's water is usable?
- What is salinity and how does it affect the amount of water we can use?
- Is usable water for humans the same as habitable water for primitive life?

Although the Earth's surface is about 71% covered by water, most of this water is in the oceans, which we cannot use because of its high salinity, or it exists as ice trapped in glaciers and ice caps, or it is located underground. Only a tiny fraction of Earth's is easily accessible and fresh water for human uses.
In Activity 2, "Where can you find water in the solar system?" youth explore the physical properties of planetary bodies in our solar system and the different reservoirs of water on those planetary bodies using a deck of planetary information cards.

Activity 2 Guiding Questions

- Where is the most water found in the solar system?
- What kind of water is available in the solar system and in what planetary bodies?

The majority of water in the solar system is found in the outer solar system among the gaseous planets and their moons. The most water among the rocky planets close to the Sun is found on Earth.

In Activity 3, "Choose a reservoir to explore," groups combine the information they have learned in the previous activities to choose a potential water reservoir to explore, share this selection with the full group, state why they want to explore it (primitive life or human use), and explain their reasoning and the evidence they found to support their choice.

Activity 3 Guiding Questions

- Is any of the water elsewhere in the solar system potentially habitable for primitive life?
- Is any of the water elsewhere in the solar system accessible and usable for potential future astronauts or future human colonies?

Most of the liquid water in the solar system outside Earth is found in subsurface reservoirs. This water may be more promising for primitive life than it is for human use, but youth can choose and use their imaginations as long as their claims are supported by information learned and evidence gathered in the unit.

Educator Background

Water in the Solar System

When the solar system formed from interstellar gas and dust, the planets closer to the Sun (Mercury, Venus, Earth, and Mars) had little water because it was so hot. Farther from the Sun, water ice was stable on the surface of planets and moons, so it is much more common in the outer solar system. Some of the water on Earth and Mars possibly came from impacts with comets or icy asteroids from farther out in the solar system where there was more water. Many of the moons in the outer solar system are made partly or mostly of water ice. For example, many large icy moons like Titan, Ganymede, and Triton contain more water than Earth in the form of ice. Also, Saturn's rings are mostly made of water ice. (Note: we often specify "water ice" when talking about frozen water because in the outer solar system it is cold enough for other things, like carbon dioxide, methane, ammonia, and nitrogen to also freeze into solid ice.) Among the planets of the inner solar system (closer to the Sun than the Main Asteroid Belt), Earth has the most water. Mercury and Earth's moon have a very small amount of water ice trapped in cold craters near their poles where the Sun never shines. Venus' surface is hotter than an oven (864 °F, 462 °C), and it has very thick carbon dioxide atmosphere with very small amounts of water vapor. Measurements of the atmosphere show that Venus probably used to have more water, but it has all been lost to space. It was boiled off the surface because of its high temperatures and then blown out of the atmosphere by the solar wind. Mars also lost much of its original water, but still has some water stored as ice beneath the surface and at the poles.

Water is essential to all life as we know it, so it is an important resource to look for elsewhere in the solar system. Scientists propose that water is the best place to look for extraterrestrial life outside our planet. Future astronauts will need to find, generate, and reuse water to survive long duration spaceflights.

Vocabulary

Astronomical Unit (AU): The average distance from the center of the Earth to the center of the Sun (93 million miles, 149.6 million kilometers).

Conductivity: A measure of water's ability to pass electrical current. This ability is directly related to the concentration of ions in the water. These conductive ions often come from dissolved salts.

Extremophile: A microorganism that lives in conditions of extreme temperature, acidity, alkalinity, or chemical concentration.

Habitability: As we know it on earth, a habitable environment is one that has water, a source of carbon for organism metabolism, and a source of energy to fuel that organism metabolism.

Ions: Charged particles. Ions are atoms or molecules with a net electric charge due to the gain or loss of electrons.

Kuiper Belt: A donut-shaped region of icy bodies beyond the orbit of Neptune.

Main Asteroid Belt: A region in the solar system located roughly between the orbits of Mars and Jupiter that is occupied by numerous irregularly shaped bodies called asteroids or minor planets.

pH: pH is a measure of hydrogen ion concentration, which indicates if a solution is acidic or basic. The pH scale measures the relative acidity of a substance. It ranges from 1 to 14 where 7 is neutral, greater than 7 is basic, and less than 7 is acidic.

Salinity: The concentration of dissolved salt in water.

Water availability: The presence or absence of water. How much water is available on

Earth or another planetary body can be measured or estimated.

Water accessibility: A measure of how easily water can be obtained. The more effort or energy it takes to access water depends on its location and its physical state. For example, liquid water at the surface is easily accessible. Water that is frozen or located deep underground is less accessible.

Water usability: A measure of how usable water is by humans for consumption (drinking and cooking), agriculture (growing food), and hygiene (cleaning things and washing away waste). To be usable, water must be relatively pure (not contaminated, dirty, polluted, or too salty), and water must be in liquid form.

Materials List & Preparation

Unit Materials List

Quantity	Item
1 per youth	Science Notebook
2 per group of 3	Clear plastic cups
1 per group of 3	Permanent or wet-erase marker
1 per youth	Pencils
1 deck per group of 3	Planetary cards
1 roll for entire group	Tape
1 per group of 3	Calculators
1 cup for entire group	Table salt (any kind - 3 to 4 tablespoons per group of 3)
1 for entire group	Potato cut into slices (2 per group)
1 per group of 3	Tablespoon
1 per group of 3	Stirring spoon or stick

Preparation for Entire Unit (1-2 hrs)

Read through the entire PLANETS Science Series educator guide to learn more about the science content in this unit. This is intended to help educators become familiar with science concepts related to how water was distributed in the formation of the solar system and thereafter. Educators can decide which concepts and vocabulary are most appropriate for their group.

Activity 1

1. Set-up a device with a projector and internet access, view and test video links:
   - » Video on Water Availability, Accessibility, Usability
     https://planets-stem.org/water-in-extreme-environments
   - » Optional video on pH:
     https://www.youtube.com/watch?v=I18K2upEHLc
   - » Optional Salinity Video
     https://www.youtube.com/watch?v=jzTBR2APU-k
   - » Optional video on waste water treatment:
     https://www.youtube.com/watch?v=8isr9nSDCK4
   - » Video on Extremophiles
     https://www.youtube.com/watch?v=DVox3i1pcpQ

2. Cut potato(es) into similar sized french fry style slices. Each group of 3 needs 2 slices.

3. Print one Science Notebook for each youth, in color if possible. These will be used in Activities 1-3.

Activity 2

1. Print one set of Planetary Cards, double-sided, in color if possible, for each group of 3. There are several sheets of cards (front and back) that form a deck. Cut the cards with a paper cutter to make individual stacks of 54 cards per deck. These will be used in Activities 2 and 3.

Optional: Consider laminating the self-printed cards or using page protectors to preserve materials for future use.

2. Print out the four Water in the Solar System Chart (pp. 36-39).

Activity 3

There is no additional preparation for this Activity.