National Aeronautics and
Space Administration

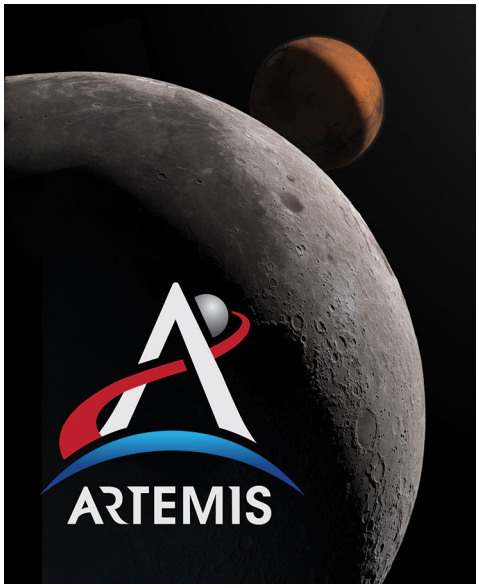
21st Century Community Learning Center
NASA Engineering Design Challenge

Lunar Water

STEM Facilitation Guide

NASA: Why We Explore

The United States is a world leader in the pursuit of new frontiers, discoveries, and knowledge. The vision of NASA is to discover and expand knowledge for the benefit of humanity. Formed in 1958, NASA has amassed a rich history of unique scientific and technological achievements in human spaceflight. We will move forward to the Moon, this time to stay. Then, we will take what we have learned on the Moon and travel to Mars with a new generation of explorers.



The Artemis program will take human explorers to the Moon and to Mars.

The Artemis program is the first step to begin the next era of exploration. NASA will establish a sustainable human presence on the Moon, with the goal of sending humans on to Mars. Our next journey into space will include innovative technologies for exploring more of the lunar surface and working in extreme planetary environments. The journey will continue as we expand our understanding of living on the Moon and look to sending astronauts to Mars as the next giant leap. The future crews of interplanetary explorers will be composed of our current elementary school, middle school, and high school students.

NASA is currently building the infrastructure for expanding human exploration into the solar system with the Space Launch System (SLS) rocket and the Orion spacecraft. The SLS will be the most powerful rocket in the world and will allow NASA to send astronauts farther into space than ever before. The Orion spacecraft will carry up to four astronauts beyond low Earth orbit and return them safely to the Earth.

As part of the Artemis program, the Orion spacecraft will carry a crew of four astronauts beyond low Earth orbit to the Moon and to Mars.

Through the Artemis program, NASA will establish a sustainable human presence on the Moon, and a new era of exploration will begin. NASA will land the first woman and the next man on the Moon by 2024 and will establish a sustainable lunar presence by 2028. However, many engineering challenges confront NASA's scientists and engineers. For Artemis to become a reality, lunar landers must be reengineered and enhancements must be made to the astronauts' spacesuits. Eventually, a lunar outpost called Gateway will be designed and constructed in lunar orbit.

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Introduction to the Engineering Design Challenge

NASA engineer Matt Mansell is shown with containers illustrating the Environmental Control and Life Support System (ECLSS) for recycling water and air aboard the International Space Station. A mockup of the ECLSS is in the background. (NASA)

Facilitator's Overview

The NASA STEM Engagement team has created an engineering design challenge (EDC) that will guide students through the engineering design process (EDP) as they develop a solution to an authentic NASA mission-centered challenge.

The EDC is a standards-based investigation that encourages students to collaborate as a team and construct a prototype representing their solution. The EDC provides students with opportunities to engage their 21st-century skills and explore science, technology, engineering, and mathematics (STEM) careers as they solve a challenge that resembles a current NASA engineering challenge.

This NASA STEM Facilitation Guide is organized into three sections:

1. The **Introduction** contains an overview of the EDP and the challenge. Facilitators will find information that describes the instructional program and the academic content standards that serve as the foundation for the challenge. A Pacing Guide is included to assist facilitators in planning both the flow and the timing of the instructional program.
2. The **Facilitator Instructions** contain the lesson plans, STEM activities, and program setup information that will be needed to implement the challenge.
3. The **Student Journal** contains the resources each student team will need to complete the challenge and produce their team presentation. Each page of the Student Journal corresponds with the Facilitator Instructions. When the challenge begins, facilitators will need to provide each student with an individual copy of the Student Journal.

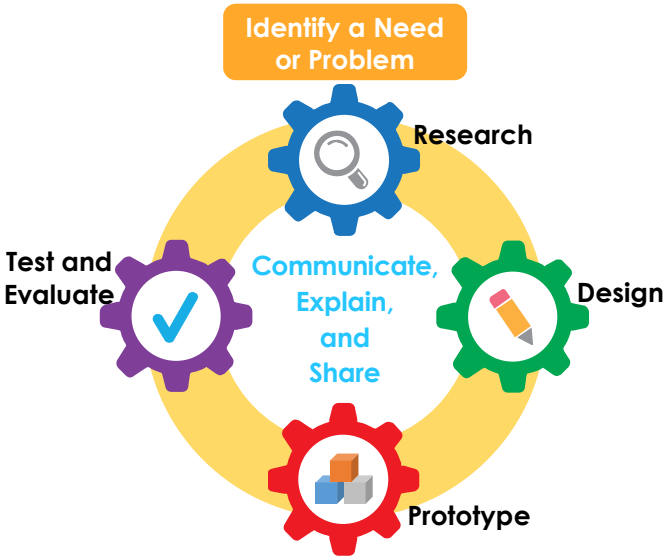
What is the Engineering Design Process (EDP)?

The EDP is a systematic approach to solving an engineering problem. NASA engineers work through each phase of the EDP to test their prototypes, create innovative solutions, and develop new technologies. The EDP begins by identifying a need or a problem. With no fixed path through the EDP, NASA engineers have the flexibility to move in and out of each EDP phase as they design, test, and improve their prototypes. Throughout each EDP phase, NASA engineers communicate, explain, and share their discoveries and team decisions as they construct prototypes, make improvements, and engineer solutions to various challenges.

What is an Engineering Design Challenge (EDC)?

The EDC is designed to be inquiry based. Each student team will explore one of the challenges NASA faces as humans begin to travel beyond low Earth orbit and explore the solar system. Teams of students will follow the EDP as they complete the STEM activities and develop a prototype that meets the criteria and constraints of the challenge. Each EDC embraces teamwork and encourages students to experience the same engineering process followed by NASA engineers and scientists.

Engineering Design Process



Engineering design process prototype. Prototype and accompanying text adapted from 2016 Massachusetts Science and Technology/Engineering Curriculum Framework, Massachusetts Department of Elementary and Secondary Education, http://www.doe.mass.edu/frameworks/scitech/2016-04.pdf.

Identify a Need or Problem

This phase of the engineering design process (EDP) allows students to ask: How can we design, build, test, and improve a prototype that will meet the criteria and constraints of the challenge? Students will explore a NASA challenge that requires their team to engineer a solution.

Research

During the Research phase, students will locate answers to their questions by exploring the internet, delving into NASA resources, and interviewing a NASA scientist or engineer.

Design

In the Design phase, each student will draw a prototype that could solve the challenge. Team members will combine their ideas and design into one team drawing that will meet all the criteria and constraints of the challenge.

Prototype

Throughout the Prototype phase, students will work as a team to construct their proposed prototype according to their drawing.

Test and Evaluate

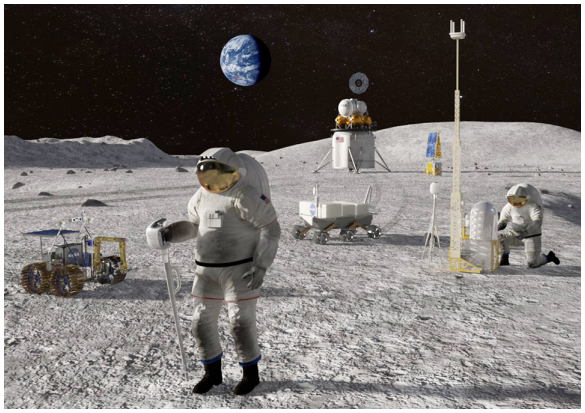
In the Test and Evaluate phase, the prototype will be subjected to tests to determine its ability to meet all the criteria and constraints of the challenge. From each of the tests, students will gather and evaluate their data in order to improve the design of their prototype.

Communicate, Explain, and Share

During each phase, teams will record and share their progress through the EDP. Teams can communicate their design solutions, share their ideas with others, and explain each phase of the EDP.

Engineering Design Challenge: Lunar Water

Scenario



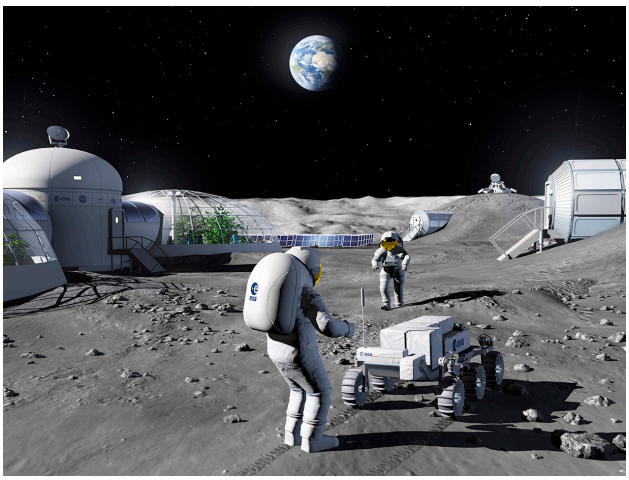
Artist's concept of astronauts walking on the Moon's surface during an Artemis mission. (NASA)

While living on the Moon, it is essential that water consumed in the lunar habitat is recycled, purified, and reused. Because of the limited-weight requirements to ship cargo on the Space Launch System and Orion spacecraft, the amount of water that can be transported and supplied for long-term missions must be precisely calculated.

All the water used by the astronauts on the International Space Station (ISS) is recycled, purified, and returned back into the ISS water systems. In a space habitat, this wastewater—also known as gray water—includes moisture exhaled by the astronauts, sweat from their workouts, and water from food preparation, shaving, and the bathroom shower.

During the Artemis program, the gray water will be recycled, purified, and reused both on the Gateway and in the lunar habitat. For the lunar crew living and working on the Moon, the purified water must have a pH range of 6.0 to 8.5 and be clear of all debris. It should also be odorless.

Lunar Water Challenge



Artist's impression of a multidome lunar base, based on a three-dimensional (3D) printing concept. Robots will cover the inflated domes with a layer of 3D-printed lunar regolith to help protect occupants against space radiation and micrometeoroids. (ESA, P. Carril)

The Lunar Water Challenge question is this: How can gray water be recycled, purified, and reused so that it can sustain our astronauts in the lunar habitat?

The challenge is for each team to design, develop, and test a water filter that will recycle, repurpose, and transform gray wastewater into purified drinking water for the lunar habitat.

To begin, each team will need to develop a water filter that consists of both a container and filtering material that will clean the pollutants and contaminants out of the water. The water filter will have an opening where the gray water is poured into the filter. Once the gray water has drained through the filter, the purified water will be collected in a graduated cylinder.

The second part of the Lunar Water Challenge will address the filtration materials themselves. Unlike on Earth, the used filter material cannot be distributed or buried. Each team will provide recommendations or suggestions describing the safest way to process the used filter material, which now contains contaminants that have been separated from the water.

Challenge Guidelines

Student teams will

1. Gather and record test data that describes both the clean water (bottled drinking water) and the gray water (four parts water and one part Italian salad dressing). Record pH levels and observations on odor, debris, and contaminants.
2. Measure and record the mass of the filtration materials used in the water filter in grams (g).
3. Using a graduated cylinder, measure and record the following:
   a. Amount of gray water to be poured into the filter
   b. Amount of water that drains out of the filter

This is just one example of a lunar water container that could hold the filtration materials.

4. With a timer, measure and record the amount of time it takes the gray water to seep through the filter.
5. Once the water filtration process is complete, develop a disposal plan that includes suggestions on how to safely dispose of the filtration material without dispersing it on the lunar surface.

Challenge Criteria

Develop a water filter that will clean 250 mL of gray water as determined by the following four tests:

1. pH Scale Test: The pH of the filtered water must measure as neutral (between 6.5 and 7).
2. Debris Test: The filtered water must be observed as clear, with no floating debris.
3. Odor Test: The filtered water must not smell like Italian salad dressing.
4. Contaminants Test: All pollutants and contaminants that were in the gray water must be removed by the filter.

Challenge Constraints

1. The filter must process 250 mL of water.
2. The mass of the filtration materials (up to three different types) together with the container must not exceed 1,000 g of mass.
3. The graduated cylinder used to collect the discharged water draining through the filter must be large enough to accommodate the filtered water.

Pacing Guide

The Pacing Guide offers a suggested timeline for each phase of the engineering design process (EDP). Facilitators may condense or expand the schedule to accommodate the needs and explorations of their student teams. This challenge may be completed in an estimated 20 sessions, with each session approximately 1 hour. At the completion of each EDP phase, students will communicate, explain, and share their discoveries, successes, and understandings.

Activity	Sessions
Introduction • Complete the Team Building activities • Explore NASA Mission Background and careers • Complete the STEM Investigations • Investigate each phase of the EDP	2 sessions
Identify a Need or Problem • Explore the challenge scenario and watch the introductory video • Identify the criteria and the constraints of the challenge	2 sessions
Research • Brainstorm research questions related to the challenge scenario • Complete a KWL chart • Connect with a NASA scientist or engineer	3 sessions
Design • Complete an individual drawing of the prototype based on the challenge scenario, criteria, and constraints • Evaluate each of the individual drawings for strength and unique ideas • Combine all of the individual drawings and ideas into a team drawing	3 sessions
Prototype • Construct a prototype using the team drawing • Evaluate the prototype against the criteria and constraints • Create a budget worksheet that will record and calculate the material costs • Demonstrate the ability to work effectively and respectfully with a team	3 sessions
Test and Evaluate • Complete the tests on the prototype according to the criteria and constraints of the challenge • Collect and analyze data from each of the tests • Determine how to best improve the prototype	3 sessions
Student Team Presentation • Collect photos and videos that will illustrate the process the team followed to complete the challenge • Represent all phases of the EDP in the student team presentation • Summarize each of the team's successes and challenges in the presentation	4 sessions

STEM Standards

The Lunar Water Challenge is designed on a foundation of science, technology, engineering, and mathematics (STEM) learning standards. Standards and objectives from each of the four disciplines are interwoven with 21st-century skills so that students can explore the academic concepts while engaging their problem-solving skills, collaborating as a team, and developing challenge solutions through the application of critical and creative thinking.

Next Generation Science Standards: Science Content Standard
https://www.nextgenscience.org/search-standards

Science Content Standard

- **MS–LS2–5**: Evaluate competing design solutions for maintaining biodiversity and ecosystem services such as water purification.

Cross-Cutting Concept of Cause and Effect

- Cause-and-effect relationships are routinely identified, tested, and used to explain change. Events that occur together regularly might or might not be a cause-and-effect relationship.

International Society for Technology in Education Standards
https://www.iste.org/standards/for-students

Creative Communicator Standard

- Students communicate clearly and express themselves creatively for a variety of purposes using the platforms, tools, styles, formats, and digital media appropriate to their goals.
- Students choose the appropriate platforms and tools for meeting the desired objectives of their creation or communication.
- Students communicate complex ideas clearly and effectively by creating or using a variety of digital objects such as visualizations, models, or simulations.

National Council of Teachers of Mathematics
https://www.nctm.org/Standards-and-Positions/Principles-and-Standards/Measurement/
https://www.nctm.org/Standards-and-Positions/Principles-and-Standards/Data-Analysis-and-Probability/

Grades 6 to 8 Expectations: In grades 6 to 8, each and every student should

- Understand both metric and customary systems of measurement.
- Select and apply techniques and tools to accurately find length, area, volume, and angle measures to appropriate levels of precision.
- Formulate questions, design studies, and collect data about a characteristic shared by two populations or different characteristics within one population.
- Select, create, and use appropriate graphical representations of data, including histograms, box plots, and scatterplots.
- Use conjectures to formulate new questions and plan new studies to answer them.

Next Generation Science Standards: Engineering Standards https://www.nextgenscience.org/pe/ms-ets1-1-engineering-design
• **MS–ETS1–1** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. • **MS–ETS1–2** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. • **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. • **MS–ETS1–4** Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

21st-Century Skills www.p21.org
Critical Thinking • Make judgments and decisions by effectively analyzing and evaluating evidence, arguments, claims, and beliefs. • Interpret information and draw conclusions based on the best analysis. ***Collaboration*** • Demonstrate ability to work effectively and respectfully with diverse teams. • Exercise flexibility and willingness to be helpful in making necessary compromises to accomplish a common goal. ***Communication*** • Articulate thoughts and ideas effectively using oral, written, and nonverbal communication skills in a variety of forms and contexts. • Use multiple media and technologies. ***Creativity*** • Use a wide range of idea creation techniques (such as brainstorming). • Develop, implement, and communicate new ideas to others effectively. • View failure as an opportunity to learn.

Safety

Safety is a special concern for all engineering design challenges (EDCs) and STEM-based activities. The academic content standards include recommendations and suggestions for developing a safe learning environment both in the classroom and in the laboratory. School administrators, teachers, and facilitators can provide and promote a learning environment that is safe and supportive for student teams as they explore, build, and test their prototypes.

Facilitators should

- Maintain a safe environment where student teams can have access to construction materials and school supplies needed for all phases of the challenge.
- Approve all Design phase drawings before student teams begin to build their prototypes.
- Identify unstable structural designs and potentially hazardous combinations of materials during each phase of the challenge.
- Ensure that the resources are clean, without exposed sharp edges.
- Inspect building materials for damage and make them available to student teams in good repair.
- Prohibit students from using additional building materials without prior approval.
- Create a safe learning environment for students to participate and ask questions.

Students should

- Make safety a priority during all challenge activities.
- Wear safety goggles when conducting all investigations.
- Demonstrate courtesy and respect for ideas expressed by others in the group.
- Use tools and construction equipment in a safe manner.
- Assume responsibility for their own safety and the safety of others.
- Follow instructions carefully and completely.

Providing a safe learning environment will ensure that student teams enjoy rich learning experiences as they progress through the engineering design process and explore this NASA EDC.

Safety Tips

While implementing the Lunar Water Challenge, advise students to safely smell the gray water to identify the presence of Italian salad dressing. Students should employ a wafting technique to smell the water rather than smelling the water directly. Also remind students not to taste the gray water or the filtered water because of potential contaminants.

Recommended Materials

The equipment and building materials required to complete the challenge can be acquired by requesting donations of recyclable materials. Additional building materials can be added to the materials table as they are acquired from a variety of sources.

Team Table Supplies

Each team will receive the following items at their team table:

- Digital scale or balance
- Timer
- Meterstick and metric rulers
- Tape (various types)
- Glue
- Staplers and staples
- Scissors
- Colored pencils and markers
- School supplies
- Safety goggles for each student

Household supplies that could be used as construction materials for the challenge.

Materials Table Supplies

Place the following supplies on the materials table in clear plastic bags or small storage containers during the Prototype phase of the EDP. On each bag or container, affix a label with the price per piece. This will be used to calculate the total supply cost on the Budget Worksheet.

Lunar Water Supplies

- Aquarium gravel
- Charcoal chips
- Cheesecloth
- Coffee filter
- Fabric swatches
- Cotton patches
- Sand
- Empty plastic water bottles

General Supplies

- 16-oz clear drinking cups
- Cardstock and file folders
- Craft sticks, lollipop sticks, or tongue depressors
- Dowel rods (various sizes)
- Heavy-duty aluminum foil
- Paper (printer, construction, waxed, and grid)
- Paper bags
- Plastic wrap
- Polystyrene cups
- Poster board
- Rubberbands
- Paper towel rolls
- Plastic water bottles
- Recycled materials
- Craft supplies

Lunar Water Testing Area Supplies

- Italian dressing
- Litmus paper
- Graduated cylinders
- Table covering

Vocabulary Support

This page includes suggestions and instructional ideas that will help to teach the challenge vocabulary. Facilitators are encouraged to add developmentally appropriate activities for student teams to explore.

Criteria and Constraints

Within any engineering design challenge, students are presented with the challenge scenario, the criteria, and the constraints for their prototype.

- The **criteria** describe all the successful functions of the prototype, including what the prototype must be able to accomplish when it is completed.
- The **constraints** consist of the limitations that are placed on the design, including the size, mass, or cost. The challenge constraints describe what the prototype cannot do or the restrictions that must be considered in the design.

Vocabulary Support Activities

The following suggestions will help students explore and understand the challenge vocabulary:

1. Facilitators or students can create a vocabulary wall to display challenge vocabulary words with their definitions.
2. Student teams can construct and play a Vocabulary Bingo game to review vocabulary words and their definitions.
3. Student teams can design and illustrate a dictionary containing the challenge words and definitions for their class.
4. Students can construct a foldable that can be used to record and review challenge vocabulary.

Students can explore the Lunar Water Challenge vocabulary through its applications both on the Earth and on the Moon. Many of the processes and characteristics of water are affected by gravity and atmospheric conditions. Water will behave much differently on the Moon than it does on the Earth. Vocabulary that describes the characteristics of water on Earth may need to be modified to describe the behaviors of water on the Moon.

Vocabulary List

Acidity. Values on the pH scale from 0 to 7 indicate acidity.

Aerodynamics. The qualities of an object that affect how easily it is able to move through the air.

Alkalinity. Values on the pH scale from 7 to 14 indicate alkalinity.

Constraints. Limits placed on a design due to available resources and environment.

Criteria. Standards by which something may be judged or decided.

Dimension. A physical property of a mass, length, or time, or a combination of any or all.

Exploration. The act of systematically investigating an objective for the purpose of discovery.

Filtration system. A system or process that allows material to pass through a filter.

Gravity. The force that attracts a body toward the center of the Earth or toward any other physical body having mass.

Iteration. One cycle of a repetitive process.

Litmus paper. Paper that is treated so that it will change color to indicate the pH of a solution.

Lunar habitat. Place or environment on the Moon that will support human life.

Mass. A unified body of matter without any specific shape.

Neutrality. The pH scale value of distilled water is regarded as neutral, or a 7 on the pH scale. In the United States, natural water falls between 6.5 and 8.5 on this scale, with 7.0 being neutral.

pH. The measure of acidity and alkalinity of a solution on a scale from 0 to 14. Acidic substances have lower pH, and alkaline (basic) substances have higher pH.

Recycle. To send objects through a series of changes or treatments so they are available for reuse.

Reuse. To use objects again, especially in a different way or after being reclaimed or reprocessed.

Weight. The measure of the pull of gravity on an object.

Facilitator Instructions

Team Building

As team members employ their 21st-century skills of collaboration, communication, creativity, and critical thinking, the team will engineer a prototype that meets the criteria and constraints of the challenge. Teams of no more than four students will work together to complete the challenge. All team members can contribute to the group discussions as they combine their design ideas, make suggestions for improvements, and build and test their prototypes. The following team-building activities can help the team begin to work together.

Assign a Gallery Wall. Each team can be assigned a designated wall space where they can display their team name, mission patch, and motto along with all of the team's design drawings for the challenge. For temporary displays, poster board or bulletin board paper can be easily stored between student meetings.

Establish a team name. Many NASA teams are named based on their assigned challenge or mission. Often an acronym is used to identity a mission or a team.

Design a mission patch. Teams that work on NASA missions are unified under a mission patch designed with symbols and artwork to identify the challenge. The names of each team member can be included on the mission patch. Information on NASA mission patches can be found at https://history.nasa.gov/mission_patches.html.

Create a group motto. This inspirational sentence describes the core goal of the team's work. It describes the vision of the team and their task.

Team Roles

As students begin to work together, their individual strengths and talents will become apparent. Students can volunteer or be assigned roles that are vital to completing the challenge. Throughout the engineering design process, team roles can be rotated to offer each student an opportunity to participate in each team position. Remember that all team members should serve as builders and engineers for the team.

Engineer: Sketches and records the design ideas generated by the team. The engineer collects data and directs the testing of the prototype.

Videographer: Records and organizes data for the presentation. The videographer designs a storyboard and produces the team presentation, which documents each phase of the engineering design process.

Accountant: Records and calculates the cost of the prototype as materials are purchased from the supply table. The accountant keeps the project within the established budget.

Manager: Communicates the team's needs and questions. The manager also keeps track of the team's progress and maintains all documents.

NASA Mission Background

What is NASA?

The National Aeronautics and Space Administration (NASA) has landed humans on the Moon, sent spacecraft to the Sun, explored every planet in the solar system, and launched robotic explorers beyond the solar system. Over the last 60 years, NASA has continued to push the boundaries with innovative aeronautics research that has dramatically changed the way we build and fly airplanes. NASA has also completed the reconnaissance of our solar system, with intense investigations of all the planets and solar-orbiting objects. From John Glenn's 1962 historic orbit of the Earth, through the Apollo missions and the Space Shuttle era, to the International Space Station (ISS), NASA has pioneered manned spaceflight. Videos and other educational resources available for student use can be found at www.nasa.gov/glenn.

What is Artemis?

The Artemis program will send the first woman and the next man to the Moon by 2024 and develop a sustainable human presence on the Moon by 2028. The program takes its name from the twin sister of Apollo and the goddess of the Moon in Greek mythology. As humans travel farther from Earth, we must learn how to sustain human life in the extreme environment of space. Advanced engineering and new technologies will be essential to accomplish the goals of Artemis. Spacesuit designs will enable astronauts to live and work in the extreme environmental conditions of space, including radiation, temperature extremes, and microgravity. In orbit around the Moon, the small spaceship known as Gateway will provide access to the lunar surface with living quarters for astronauts, a laboratory for science and research, and ports for visiting spacecraft. Educational resources, mission information, and descriptions of the Artemis program can be found at www.nasa.gov. Students can find a helpful video describing the Artemis program at https://www.nasa.gov/what-is-artemis.

The Artemis coin, with a portrait of the Greek Goddess Artemis is illustrated in the highlights and shadows of the crescent Moon topography. (NASA)

What are the characteristics of the Moon?

Earth's Moon is the only place outside of low Earth orbit where humans have walked on another celestial body. The Moon was formed millions of years ago when a large celestial body collided with the Earth. Our Moon is the fifth largest of the approximately 190 moons orbiting planets in our solar system. Because of the gravitational forces of the Moon on the Earth, the movement of the tides is directly related to the lunar cycle. NASA is currently operating the Lunar Reconnaissance Orbiter, which is orbiting the Moon and collecting vital data describing its extreme environment. The following NASA websites can provide educational supports and additional information for students to explore:

The near side of the Moon always faces the Earth.

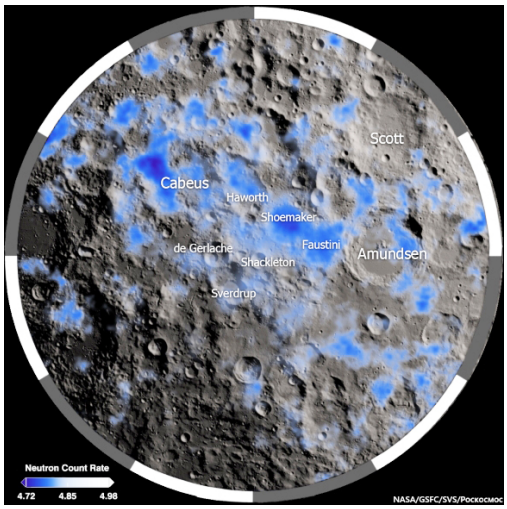
https://moon.nasa.gov/

https://solarsystem.nasa.gov/news/890/who-has-walked-on-the-moon/

https://www.nasa.gov/moon

Is there water on the Moon?

The discovery of water on the Moon holds promise for both science and human exploration. NASA has found water inside lunar samples and in the permanently shadowed craters near the South Pole. The Lunar Reconnaissance Orbiter mission data shows some lunar polar regions may contain abundant water ice deposits. Understanding the sources and concentrations of this water will help us understand how the Moon formed and the details related to its geological history. NASA scientists and engineers theorize that the poles of the Moon may hold millions of tons of water ice. After extracting the ice from the regolith (soil), the water molecules can be split into their components of oxygen and hydrogen, which can serve as sources of power for the lunar explorers. For additional information and educational resources, visit www.nasa.gov and https://moon.nasa.gov/resources/335/water-on-the-moon/.



Lunar Reconnaissance Orbiter observations indicate that the Cabeus, Shoemaker, and Faustini craters show great potential for containing subsurface ice. (NASA)

STEM Investigation: Science—What Is pH?

The goal of this STEM Investigation is for students to investigate a science concept that will be foundational for the challenge. The STEM Investigation will also serve as a team-building activity and an opportunity to develop students' 21st-century skills.

Objectives

1. Students will investigate the impact and effect of pH on drinking water.
2. Students will identify the pH of several liquids.

Guiding Questions

1. How will the pH of water be measured and used to determine water safety?
2. How can the pH of several liquids be determined?

Materials

- Litmus paper
- Bottled water
- Orange juice
- Liquid laundry soap

Instructional Procedures

Step 1

1. Students can do an internet search to find images of the pH scale.
2. Students can do an internet search to identify different types of liquids that would measure as acids, bases, and neutrals on the pH scale.

Step 2

1. Students can test a variety of liquids for their place on the pH scale.
2. Students can record their test data in the table in the Student Journal. Extra rows are available for students to test additional liquids.

Discussion Questions

1. How is the pH of safe drinking water measured and determined?
2. Why would drinking water that tests as an acid or a base be harmful to drink?

STEM Investigation: Math—How Long Does It Take Water To Drain Out of Sand?

The goal of this STEM Investigation is to explore math skills and concepts that will be foundational to developing and testing a prototype for the challenge. Throughout the engineering design process, students will be asked to record and analyze data that represents time and mass. Students will need to be able to manage their data both in a table and on a line graph. The mathematics skills and concepts embedded in this investigation will play a vital role in developing a solution to the challenge. In the following activity, students will collect data describing how thawing water can be extracted from the frozen lunar surface.

Objectives

1. Students will measure the time it takes water to drain out of sand.
2. Students will record their time and volume measurements in a table.
3. Students will construct a line graph to visualize their data.

Guiding Questions

1. How can we record and analyze the data from the investigation?
2. How can we display our data on a line graph?

Materials

- Sand in a plastic container
- 250 mL of water
- Coffee filter
- Stopwatch
- Graduated cylinder

Instructional Procedures

Step 1

1. In a plastic container filled with sand, freeze 250 mL of water.
2. Have students engineer a stand that will hold the container filled with sand in an inverted position.
3. Under the container, place a layer of coffee filters that will catch any sand from the container as it thaws.
4. Place a graduated cylinder under the stand to catch and measure any liquid water.

Step 2

1. Every 5 minutes, record the amount of water that has drained out of the container of sand into the graduated cylinder.
2. Make a line graph displaying the amount of water that is drained out of the sand.

Discussion Questions

1. Why is it important to collect and analyze data?
2. What did you discover from your data?

STEM Investigation: Technology—How Do I Use a Spreadsheet?

The goal of this STEM Investigation is to allow student teams to investigate and explore software packages and applications that will be extremely useful throughout the engineering design process. The fear of working with technology can often stop students from investigating and exploring the rich opportunities that are available through technological applications. In this activity, students will have an opportunity to explore a spreadsheet.

Objectives

Students will enter their data into a spreadsheet.

Guiding Question

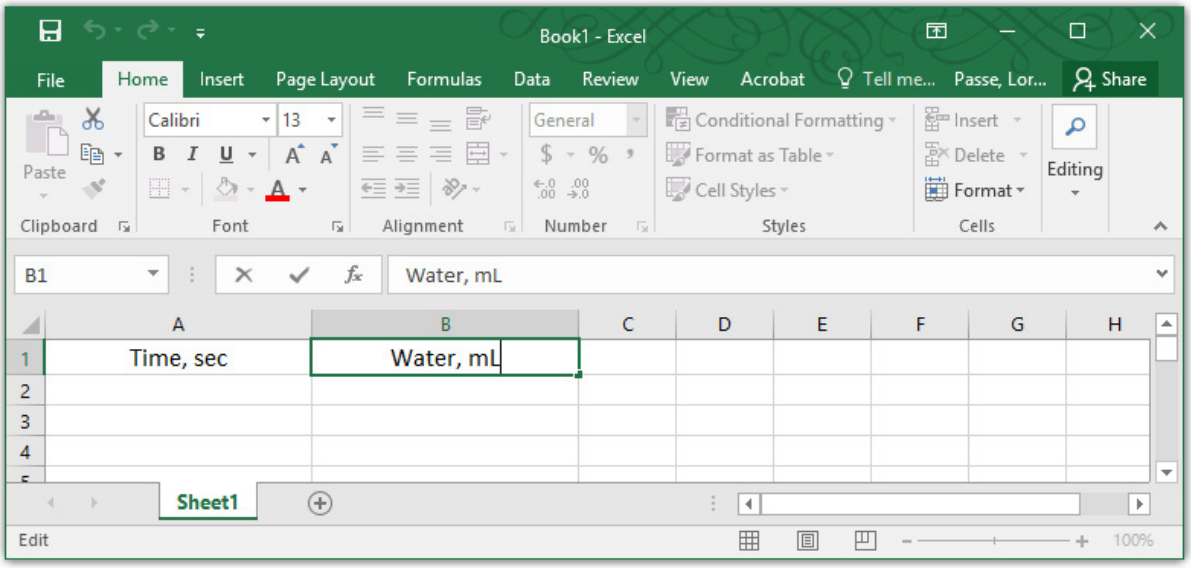
How can we record and analyze the data from the investigation in a spreadsheet?

Materials

- Data from the STEM Investigation: Math
- Spreadsheet application, such as Microsoft® Excel®

Instructional Procedures

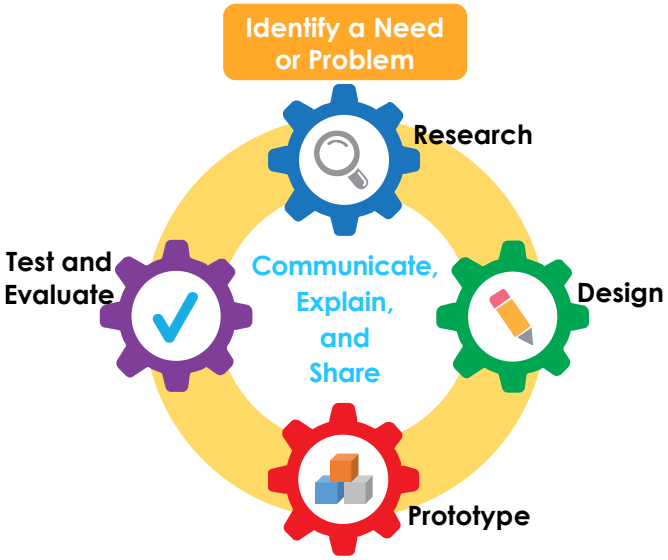
1. Open up a spreadsheet.
2. In the first row, enter two column headings for the data: **Time, sec** (seconds) and **Water, mL** (milliliters).
3. Using the data from the STEM Investigation: Math, enter each of the time measurements and corresponding water measurements into the cells of the spreadsheet. (See the sample provided here.)
4. Allow students extra time to explore the spreadsheet.
5. Have students explore the numerous instructional videos available on YouTube® that demonstrate how to use spreadsheets.
6. Have students print out their spreadsheet and tape it onto the Student Journal page.



Discussion Question

Why is a spreadsheet an important tool to use when collecting and analyzing data?

Engineering Design Process



Engineering design process prototype. Prototype and accompanying text adapted from 2016 Massachusetts Science and Technology/Engineering Curriculum Framework, Massachusetts Department of Elementary and Secondary Education, http://www.doe.mass.edu/frameworks/scitech/2016-04.pdf.

The engineering design process (EDP) is a systematic approach to solving an engineering problem. Engineers work through each phase of the EDP to build prototypes, create solutions, and develop new technologies that will provide the best solution to the challenge.

Objectives

Student teams will

1. Investigate each phase of the EDP.
2. Explore the careers and the vocabulary that are associated with the challenge.

"I Can" Statements

1. I can investigate each phase of the EDP.
2. I can explore the careers and the vocabulary found within the challenge.

Preparation

Facilitators will identify local engineers, mathematicians, scientists, or technology experts who could meet with students to discuss careers and opportunities in each of the STEM fields.

Engage

Guiding Questions

1. What are the phases of the EDP?
2. What careers are available in the fields of engineering, math, science, and technology?

Explore

Instructional Procedures

1. Show student teams the following video, which presents an overview of the EDP: https://www.nasa.gov/audience/foreducators/best/edp.html
2. Discuss each phase of the EDP with student teams. Explain both the goal and the purpose of each EDP phase and how they will lead to a solution to the challenge.
3. Construct a Word Wall that will serve as a running record of the vocabulary words and their definitions throughout the challenge. Vocabulary words can also be recorded in the Student Journal. Vocabulary is an essential part of understanding the challenge.
4. Invite local engineers, mathematicians, scientists, and technology specialists from the community to visit student teams, discuss their STEM careers, and answer students' questions.
5. Have students visit "My Everyday Extraordinary" to find out more about the people who work at NASA: https://www.nasa.gov/careers/my-everyday-extraordinary.

Explain (Cause and Effect)

Cause and effect is foundational to the EDP. Throughout the challenge, students will be asked to explain the causes and effects they observe in their designs, the construction of their prototypes, and each of the structural and environmental tests. To be successful engineers, students must understand how to handle failure and make the necessary improvements so their prototype will meet the criteria and constraints of the challenge. The goal of the Explain stage of the lesson plan is for students to identify the causes and effects that are critical within the challenge. Discussion questions are included to help with the cause and effect discussions.

Elaborate (Communicate, Explain, and Share)

Throughout the EDP, students will need to regularly communicate, explain, and share their team's progress. The teams will need to debrief their findings, discuss their prototype designs, and share their "failures."

Communicate

As students work through the EDP, developing their communication skills will enable them to describe their team's progress as they design and build their prototype. Students need to express their concerns, ask questions regarding each phase of the EDP, and describe their ideas and insights regarding their designs. Discussion questions could include "How could the design be improved for the future?"

Explain

As student teams move through each phase of the EDP, they will have the opportunity to explain their engineering thinking and articulate the process they followed to arrive at their prototype designs. Discussion questions could include "What causes and effects did the team observe during each phase of the engineering design challenge?"

Share

Sharing the results and the final designs of the engineering design challenge is an important phase of the EDP. Using a variety of media and software platforms, teams can share their

experiences through video or slide presentations. Every student on the team should be included in the conversation and the final presentation of the challenge solution. Discussion questions could include "How does your prototype meet the criteria and constraints of the challenge?"

Evaluate

Debriefing Questions

1. Describe each phase of the engineering design process.
2. What are some possible STEM careers that interest you?

Online Resource

Students can explore NASA careers, requirements to become an astronaut, and many student opportunities at https://www.nasa.gov/audience/forstudents/careers/index.html.

STEM Career Connections

This NASA for Kids video introduces engineering to students:
https://www.youtube.com/watch?v=wE-z_TJyzil

Accommodation

Students can color code each section of their Student Journal to correspond with the EDP phases.

Challenge Connections

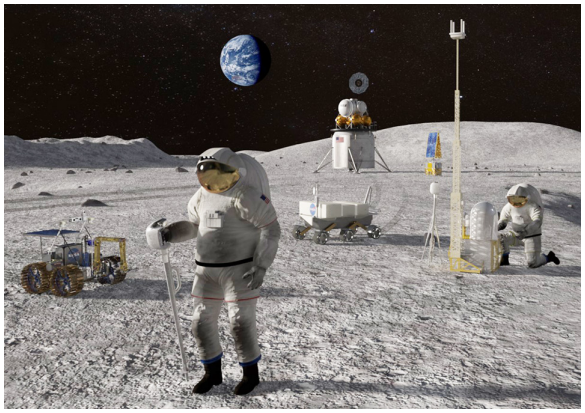
Facilitators can give teams a large whiteboard or piece of paper on which they can create a flowchart of the EDP. Students could use sticky notes or colored markers to describe each phase. During the student team presentation, teams can refer to the chart and the corresponding EDP phase.

Engineering Design Challenge: Lunar Water

Scenario

Identify a Need or Problem

While living on the Moon, it is essential that the water consumed in the lunar habitat is recycled, purified, and reused. Because of the limited-weight requirements to ship cargo on the Space Launch System (SLS) and Orion spacecraft, the amount of water that can be transported and supplied for long-term missions must be precisely calculated.



Artist's concept of astronauts walking on the Moon's surface during an Artemis mission. (NASA)

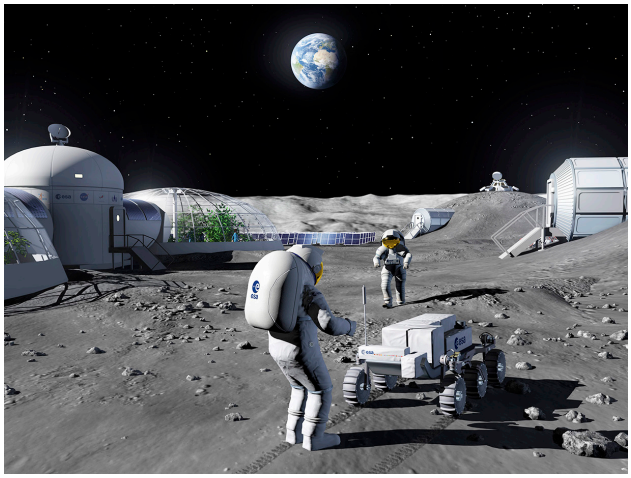
All the water used by the astronauts on the International Space Station (ISS) is recycled, purified, and returned back into the ISS water systems. In a space habitat, this wastewater—also known as gray water—includes moisture exhaled by the astronauts, sweat from their workouts, and water from food preparation, shaving, and the bathroom shower.

During the Artemis program, the gray water will be recycled, purified, and reused both on the Gateway and in the lunar habitat. For the lunar crew living and working on the Moon, the purified water must have a pH range of 6.0 to 8.5 and be clear of all debris. It should also be odorless.

Lunar Water Challenge

The Lunar Water Challenge question is this: How can gray water be recycled, purified, and reused so that it can sustain our astronauts in the lunar habitat?

The challenge is for each team to design, develop, and test a water filter that will recycle, repurpose, and transform gray wastewater into purified drinking water for the lunar habitat.



Artist's impression of a multidome lunar base, based on a three-dimensional (3D) printing concept. Robots will cover the inflated domes with a layer of 3D-printed lunar regolith to help protect occupants against space radiation and micrometeoroids. (ESA, P. Carril)

To begin, each team will need to develop a water filter that consists of both a container and filtering material that will clean the pollutants and contaminants out of the water. The water filter will have an opening where the gray water is poured into the filter. Once the gray water has drained through the filter, the purified water will be collected in a graduated cylinder.

The second part of the Lunar Water Challenge will address the filtration materials themselves. Unlike on Earth, the used filter material cannot be distributed or buried. Each team will provide recommendations or suggestions describing the safest way to process the used filter material, which now contains contaminants that have been separated from the water.

Challenge Guidelines

Identify a Need or Problem

Student teams will

1. Gather and record test data that describes both the clean water (bottled drinking water) and the gray water (four parts water and one part Italian salad dressing). Record pH levels and observations on odor, debris, and contaminants.
2. Measure and record the mass of the filtration materials used in the water filter in grams (g).
3. Using a graduated cylinder, measure and record the following:
   a. Amount of gray water to be poured into the filter
   b. Amount of water that drains out of the filter
4. With a timer, measure and record the amount of time it takes the gray water to seep through the filter.
5. Once the water filtration process is complete, develop a disposal plan that includes suggestions on how to safely dispose of the filtration material without dispersing it on the lunar surface.

This is just one example of a lunar water container that could hold the filtration materials.

Challenge Criteria

Develop a water filter that will clean 250 mL of gray water as determined by the following four tests:

1. pH Scale Test: The pH of the filtered water must measure as neutral (between 6.5 and 7).
2. Debris Test: The filtered water must be observed as clear, with no floating debris.
3. Odor Test: The filtered water must not smell like Italian salad dressing.
4. Contaminants Test: All pollutants and contaminants that were in the gray water must be removed by the filter.

Challenge Constraints

1. The filter must process 250 mL of water.
2. The mass of the filtration materials (up to three different types) together with the container must not exceed 1,000 g of mass.
3. The graduated cylinder used to collect the discharged water draining through the filter must be large enough to accommodate the filtered water.

Identify a Need or Problem

Identify a Need or Problem

The engineering design process (EDP) begins by identifying a need or a problem that a team of students can solve and improve. This phase begins by understanding the criteria and constraints of the challenge.

Objectives

Students will

1. Explore and discuss the information presented in the challenge scenario.
2. Identify the challenge criteria and constraints.
3. Communicate, explain, and share their insights and understandings regarding the challenge scenario.

"I Can" Statement

I can identify and explain the criteria and constraints of the challenge.

Preparation

Facilitators will need to make a copy of the Student Journal for each student. Students will need access to the internet to locate answers to questions about NASA missions and space travel. In addition, students will need to review the EDP, including each of its phases.

Engage

Guiding Questions

1. What are the criteria and the constraints of the challenge?
2. What is the vocabulary that is associated with the challenge?

Explore

Instructional Procedures

1. Ask each student team to read the challenge in their Student Journal.
2. Show the introductory video for the challenge. Students can complete the Introductory Video page in their Student Journals.
3. Ask students to explain the specific criteria and constraints of the design challenge. Ask students to restate the criteria and constraints in their own words.
4. Students can complete the Identify a Need or Problem pages in the Student Journal to document their work and record their data.

Explain (Cause and Effect)

After reading the challenge, conduct a team discussion to explore the challenge statement and its effects.

Discussion Questions

1. How are the Earth and the Moon similar? How are they different?
2. How will the lack of a water cycle on the Moon impact the lunar crew?
3. Why must the disposal of the filter material be considered in the design?

Elaborate (Communicate, Explain, and Share)

Identify a Need or Problem

Student teams will prepare a 1-minute script for the student team presentation, including the team name, team patch, and team motto.

Evaluate

Debriefing Questions

1. What are the criteria and constraints of the challenge?
2. What physical characteristics of the Moon are important to consider when designing the water filter?
3. Why must the data describing clean water and gray water be collected prior to the gray water flowing through the water filter?

Online Resources

1. Show the NASA Beginning Engineering Science and Technology (BEST) video "Repeatability." https://www.youtube.com/watch?v=-2Az1KDn-YM.
2. "Water on the Moon" features NASA's Lunar Reconnaissance Orbiter. https://www.youtube.com/watch?v=qYW4rTrAA5I
3. "NASA Now: Finding and Using Water on the Moon" will answer many of the students' KWL chart questions. https://www.youtube.com/watch?v=EkbUffRtjXk

STEM Career Connections

Invite a panel of different types of engineers from the local community to visit and discuss their career paths and preparations.

Accommodations

1. The criteria and constraints can be introduced to the teams one at a time so that students can think through each of the challenge requirements.
2. Student teams can construct a class poster describing the challenge, which can be referenced throughout the EDP.

Challenge Connections

Students can interview an engineer who works at a local water department. Students can explore careers and job responsibilities during their interview. They can also ask questions regarding water quality and recycling water. Information from the interview can be recorded on the KWL chart.

Research

During the Research phase, student will pose their questions regarding the challenge scenario, criteria, and constraints. Students can use resources found on the internet or conduct an interview with a NASA scientist or engineer to answer their KWL questions (What do I know? What do I need to know? What did I learn?). Student teams can locate additional information on NASA missions, STEM careers, and living in space on websites such as www.nasa.gov.

Objectives

Students will

1. Brainstorm research questions to record on the KWL chart, representing the unique STEM understanding found in the challenge scenario.
2. Complete the KWL chart by using a variety of internet sources, interviews, and data-gathering activities.
3. Connect with a NASA scientist or engineer to pose questions regarding the challenge, careers, and NASA missions.
4. Communicate, explain, and share their research findings and the reasons for the team's decisions.

"I Can" Statements

1. I can brainstorm a list of five research questions.
2. I can collect data to answer my research questions.
3. I can communicate, explain, and share the results of my research.

Preparation

Facilitators will

1. Ensure internet availability.
2. Supply research links to NASA websites.
3. Schedule a time to connect with a NASA scientist or engineer.
4. Duplicate the Research pages found in the Student Journal.

Engage

Guiding Questions

1. What are five questions that will help our team explore the challenge scenario?
2. Using a variety of resources (technology, scientist and engineer connections, information-gathering activities, etc.), what information can our team use to locate each answer from our KWL questions?
3. How can we communicate, explain, and share the results of our research, our KWL chart, and the concerns we have identified when designing our prototype?

Explore

Instructional Procedures

1. Complete the KWL chart located in the Student Journal. An Anticipated KWL Chart is provided to get the brainstorming activity started.
2. Continue to add questions to the KWL chart regarding the challenge scenario and the background information. Using a variety of sources such as the internet, scientist and engineer connections, and information-gathering activities, guide student teams to answer their KWL questions.
3. Explore NASA websites to locate video explanations and status reports regarding the current robotic missions.
4. Schedule and connect with a NASA scientist or engineer to engage in discussions regarding the Lunar Water Challenge. Students will need to prepare questions prior to the virtual connection to ask the scientist or engineer.
5. Students can add and update the KWL charts on the team's Gallery Wall.

Explain (Cause and Effect)

During the Research phase, students will explore questions focused on space travel and water found on the Moon. Students will be able to make connections to the recycling and purifying of water in their local community. Some suggested KWL chart questions are provided here. Students can also brainstorm and include their own questions about lunar water.

1. How is water recycled in my city?
2. How are impurities, pollution, and bacteria removed from the drinking water?
3. How does well water differ from city water?
4. How is water recycled on the International Space Station?
5. Is there a difference between purified water and recycled water?

Elaborate (Communicate, Explain, and Share)

Student teams will prepare a 1-minute script describing their research results for the student team presentation. The team will also include a discussion of how their research results will affect the design of their prototype.

Evaluate

Debriefing Questions

1. What data can our team use to answer the questions found on the KWL chart?
2. What information about water filtration must be included in the design of our prototype?

Online Resources

1. To answer questions about space travel, students can visit https://www.nasa.gov/audience/foreducators/stem-on-station/dayinthelife.
2. To find out more about the people who work at NASA, have students visit "My Everyday Extraordinary." https://www.nasa.gov/careers/my-everyday-extraordinary
3. One question students always present for the KWL chart is "How do astronauts go to the bathroom?" The NASA video "Space Potty" does an excellent job answering this question. https://www.youtube.com/watch?v=5WSlGRBTFNI

STEM Career Connections

During the Research phase of the EDP, students will have an opportunity to connect with a NASA scientist or engineer. During the connection, students can ask the questions they have prepared about the person's STEM career and record the information in the KWL chart.

Accommodations

1. Facilitators can provide students with guiding questions to direct and focus the team's research and can direct them to the location of data to answer their questions.
2. Students may need extra time to discuss the challenge questions and answers.

Challenge Connections

Using their research and their completed KWL chart, students can design a slide presentation describing their findings. Students can present their questions and research findings during a community event or parent night. Students' research can also be posted on the school district's website.

KWL Chart

Student teams will create a KWL chart using the Research pages in the Student Journal. Students can discuss and record their understandings along with their questions in the corresponding column of the KWL chart. Student teams can locate the answers to their questions through online research or by interviewing a NASA engineer or scientist. Facilitators can return to the KWL chart throughout the challenge as students find additional answers to their questions. An Anticipated KWL Chart follows here. It contains suggested research questions that will help students begin brainstorming.

Anticipated KWL Chart: Research

What do we know?	What do we need to know?	What did we learn?
	1. What is NASA?	
	2. What is Artemis?	
	3. How is water recycled in my city or region?	
	4. How is water recycled on the International Space Station (ISS)?	
	5.	

What do we know?

What do students already know about the challenge? In the first column, students will list what they already understand about the challenge scenario.

What do we need to know?

What are students' questions about the challenge? After a few initial questions about NASA and Artemis, the facilitator will want to focus students' brainstorming on questions about the challenge itself. These questions will be the foundation of the Research phase. They can be discussed as students do internet research or during virtual connections with NASA scientists or engineers.

What did we learn?

What have students learned during the challenge? Facilitators will record the research answers to students' questions, including students' insights and the data the teams have collected.

Virtual Connections: Scientists and Engineers

The challenge provides an opportunity for students to connect virtually with a NASA scientist or engineer. Facilitators and student teams can review their schedules and identify the best time for this connection. Teams would benefit from connecting with a NASA scientist or engineer during the Research phase to answer the questions on the KWL chart. A connection could also be extremely helpful during the Test and Evaluate phase as teams are making design improvements to their prototypes.

Students can prepare for the connection by using the following Anticipated KWL Chart with guiding questions as discussion prompts. Additionally, facilitators can prompt teams to prepare and ask questions about the engineering design process and the engineering design challenge itself. NASA scientists and engineers also welcome specific team questions about their careers and their roles with NASA missions.

Anticipated KWL Chart: Virtual Connections

What do we know?	What do we need to know?	What did we learn?
	1. What role do engineers play at NASA?	
	2. What are the roles of NASA scientists and engineers when exploring lunar water?	
	3. What improvements do you suggest we make to our prototype?	
	4.	
	5.	
	6.	
	7.	

Design

The Design phase includes developing and drawing a labeled diagram of the prototype. First, students work independently to create their own drawings. Then, as a team, students will create a drawing that represents the best of all the individual ideas.

Objectives

Students will

1. Individually, create a drawing of the prototype that represents the criteria and constraints of the challenge.
2. Evaluate the individual drawings and ideas for strengths and weaknesses.
3. Collaborate to create a team drawing of the envisioned prototype that meets the criteria and constraints of the challenge.
4. Evaluate the design drawings against the criteria and constraints of the challenge.

"I Can" Statements

1. I can create an individual drawing of a prototype that meets the criteria and constraints.
2. I can evaluate individual drawings and ideas for strengths and weaknesses.
3. I can work with my team to envision and draw a team prototype that meets the criteria and constraints.
4. I can evaluate our team's drawing so that it represents the criteria and the constraints of the challenge.

Preparation

Facilitators will provide students with the necessary supplies to complete their individual and team drawings, including paper, markers, and colored pencils.

Engage

Guiding Questions

1. As an individual, how can I create a drawing of the prototype that represents the criteria and constraints of the challenge?
2. As an individual, how can I evaluate individual drawings and ideas for strengths and weaknesses?
3. How will the team drawing of the envisioned prototype meet the criteria and constraints of the challenge?
4. Does our team drawing represent each of the criteria and constraints of the challenge?

Explore

Instructional Procedures

1. Ask each team member to individually brainstorm and make sketches representing their ideas for a prototype.
2. Students must clearly label and identify each part of their prototype, making sure it meets all the criteria and constraints of the challenge.
3. Students will need to decide the type and the order of the filtration materials that will be placed in the filter. Each filtration layer must be labeled.
4. Students will also need to design a water filter container so that gray water can be poured into the filter and clean water can be collected in a graduated cylinder.
5. Teams will choose and design the filtration materials so that they can be repurposed or disposed of.
6. During a team meeting, allocate time to discuss students' ideas and drawings with the rest of the team. Make sure students address the strengths and weaknesses of each design as well as how the design meets the criteria and constraints of the challenge.
7. Allow the team to identify how their drawing represents the criteria and the constraints of the challenge.
8. The facilitator will need to approve the team drawings of the prototype.
9. Teams can display their final team design drawing on their designated Gallery Wall.

Explain (Cause and Effect)

Throughout the design process, encourage student teams to identify possible causes within their prototype designs that will affect the quality of the clean water.

Discussion Questions

1. What filtration materials do you think will be the best to use for each layer?
2. What contaminants do you predict each layer of your filter will clean out of the gray water?
3. Explain how your filter meets the criteria and constraints of the challenge.

Elaborate (Communicate, Explain, and Share)

After completing both the individual and the team drawings of their prototype, students will develop a 1-minute script that will describe the design process and the team's decisions.

Evaluate

Debriefing Questions

1. How does my drawing represent the criteria and the constraints of the challenge?
2. How does our team drawing meet the criteria and the constraints of the challenge?

Online Resource

The video "NASA: Living on the Moon" explains what is needed for astronauts to survive in a lunar habitat. https://www.youtube.com/watch?v=TNrhADcTNBk

STEM Career Connections

Because of the unique complexities of working on the Moon, individuals in traditional STEM careers, such as hydrologists, will become important members of the lunar exploration team. Students can explore a STEM career and apply adaptations to the lunar environment.

Accommodation

Have students pick one characteristic at a time from each team member's drawing to discuss in the group.

Challenge Connections

Students can explore Earth-based water filtration products that are used in the home and in the community. Students can determine if the same product would purify the water in a lunar environment, taking into consideration the unique characteristics of the Moon.

Prototype

As a team, students will build a prototype based on the team drawing. Building materials will be revealed to students for the first time during the Prototype phase of the engineering design process. Discussions of safety protocols should also take place prior to the build.

Objectives

Students will

1. Create a prototype representing the team's design from provided building materials.
2. Evaluate the prototype against the challenge scenario, criteria, and constraints.
3. Create a budget worksheet that will record and calculate the material cost of the team's prototype within an established budget.
4. Demonstrate the ability to work effectively and respectfully with diverse teams.

"I Can" Statements

1. I can create a prototype that represents the team's design from the provided building materials.
2. I can evaluate the prototype against the challenge scenario, criteria, and constraints.
3. I can create a budget worksheet that will record and calculate the cost of the team's prototype within an established budget.
4. I can demonstrate the ability to work effectively and respectfully with diverse teams.

Preparation

Facilitators will

1. Locate and acquire building materials such as craft supplies, school supplies, and recycled materials. Donations from parents and community organizations are an economical way to acquire these materials.
2. Arbitrarily assign costs to each of the materials that are available to students. Costs should not exceed a dollar per building item.
3. Organize supplies and building materials in zip bags or plastic storage containers for easy storage and access by students.
4. Provide students with construction materials such as tape, glue, and scissors free of cost.

Engage

Guiding Questions

1. How will our team create a prototype representing the team's design from provided building materials?
2. How will our team create a budget worksheet that will record and calculate the material cost of the team's prototype within an established budget?
3. How can our team work collaboratively to communicate our ideas during the build?

Explore

Instructional Procedures

1. This will be the first introduction of the building materials to the teams. Using only the building materials provided, teams will construct a prototype based on their team drawing. Materials can be limited to a certain number to avoid hoarding and to enhance creativity. Construction materials such as tape, glue, and scissors can be provided to teams as needed at no cost.
2. For safety reasons, encourage students to wear safety goggles.
3. Team members will work together to build their prototype using their preapproved design drawings.
4. Charcoal granules must be prewashed to remove dust. This can be done in a mesh bag under a stream of water. Otherwise, black dust will appear in the filtered water.
5. Encourage and limit students to use three types of filtration materials in the filter.
6. As the team is building and constructing their prototype, students can be allocated a budget to spend on their building materials. Prior to the build, the materials will be labeled with a price. Students can record and track their material "purchases" on the Budget Worksheet.
7. Throughout the Prototype phase, students can document their construction process and team decisions with photos and video that will be included in the team presentations. Teams photos can also be displayed on the Gallery Wall.

Explain (Cause and Effect)

As students are constructing their prototypes, encourage them to explain their engineering thinking as they adapt the building materials to their prototype. Students can demonstrate the cause-and-effect relationships as they construct their water filter. These engineering insights can be recorded in the Student Journal and included in the final team presentation.

Discussion Questions

1. Why did you choose the specific filtration materials?
2. Explain the construction decisions your team made while building your prototype.
3. How does your prototype meet the criteria and constraints of the challenge?

Elaborate (Communicate, Explain, and Share)

As a team, communicate, explain, and share the reasons for the team's decisions, research, and improvements. Also explain the cost of the prototype using the Budget Worksheet. Create a 1-minute script for the student team presentation that discusses the data, the improvements to the prototype, and its cost.

Evaluate

Debriefing Questions

1. How did we create a prototype representing the team's design from available and provided building materials?
2. How did we create a prototype within the established budget for materials?
3. How did we work together collaboratively as a team to build our prototype?

Online Resource

The NASA video "We Are Going" discusses the return to the Moon and the many engineering design challenges that will need to be solved before a lunar crew can live on the Moon. https://www.youtube.com/watch?v=vl6jn-DdafM

STEM Career Connections

STEM careers include architects who design living spaces and water systems. In the lunar habitat, architects and engineers will have to work together to design lunar habitat support systems that will both sustain the crew and accommodate for the physical characteristics of the Moon. As a team, students can construct a table that lists the physical characteristics of the Moon and describes the accommodations that will have to be engineered by lunar architects.

Accommodation

Allow students extra time to complete their prototype by prioritizing one constraint or criterion before addressing the next.

Challenge Connections

Additional limits can be placed on material quantities to add complexity to the Prototype phase. (Example: A team can use only 1 m of duct tape.)

Test and Evaluate

The goal of the Test and Evaluate phase is to subject the lunar water filter prototype to a variety of structural and environmental tests that will simulate the challenge scenario. Teams should test their lunar water filter three times, recording each trial in the data chart found in the Student Journal. Using the test data, students can make improvements and modify their prototype designs.

Objectives

Students will

1. Conduct tests that will represent the criteria and constraints of the challenge.
2. Identify areas for prototype improvements based on test data.
3. Identify the reasons for the prototype's failure during the tests (if it failed) and address those issues during the redesign of the prototype.
4. Progress forward or return to previous engineering design process (EDP) phases to redesign the prototype based on new research or test data.
5. Represent and interpret data using a line graph.

"I Can" Statements

1. I can conduct tests that represent the criteria and constraints of the challenge.
2. I can identify areas to improve my prototype based on the testing data.
3. I can identify the causes and effects for prototype failure and redesign the prototype.
4. I can progress forward or return to the previous EDP phases to redesign my prototype based on new research or test data.
5. I can represent and interpret our data with a line graph.

Preparation

Facilitators will

1. Prepare a testing area where the teams can test their lunar water filter safely. Choose an area where the filter can sit undisturbed for an extended length of time. The testing area should be easily cleaned in case of spills.
2. Ensure safety during the tests by providing rubber gloves if students have allergies to any of the filtration materials or the gray water.
3. Provide graph paper as needed to construct line graphs that will represent students' data. Line graphs can be drawn on the graph paper and glued or taped into the Student Journal.

Engage

Guiding Questions

1. How will our team conduct environmental and structural tests that represent the criteria and constraints of the challenge?
2. How will our team identify areas where our lunar water filter will need improvements based on test data?
3. If the prototype failed during the tests, what were the reasons for the failure?
4. Will our team progress forward, or will we need to return to previous engineering phases to redesign the prototype based on new research or test data?
5. How can we collect and represent our data on a line graph?

Explore

Instructional Procedures

1. Teams will begin their testing by collecting data on bottled drinking water and the prepared gray water before it flows through the filter. This will serve as baseline data.
2. Each student team will conduct a water filtration test by pouring the gray water into the filter and collecting it in a graduated cylinder. In the Student Journal, students will record the results of four water tests (pH, debris, odor, and contaminants) and the time for the water to drain through the filter.
3. Based on the data from the tests, teams will make the necessary improvements to the prototype so that the challenge criteria and constraints are met.
4. Teams will represent their data on a line graph. Students may want to complete their line graphs on a separate piece of graph paper and then glue it into their Student Journals.
5. As the testing of the filter continues, the team may need to return to previous phases in the EDP in order to research new questions, modify the lunar water filter design, and/or reconstruct the prototype itself.
6. As each team redesigns their prototype, they will need to adjust the cost on their Budget Worksheet.
7. The data sheets representing the test results and photos of the design improvements made to the filter can be displayed on the team's Gallery Wall and included in the final student team presentation.

Explain (Cause and Effect)

Throughout the Test and Evaluate phase, students will identify and describe the cause-and-effect relationships that contributed to the failure and the success of their prototype. The team will return to previous phases of the EDP to redesign the prototype in order to address the failure issues.

Discussion Questions

1. What were the causes of the failures in your water filter, and how did you improve your design?
2. How does your filtered water compare with the gray water?
3. How did your test data help improve your water filter?

Elaborate (Communicate, Explain, and Share)

Create a 1-minute script for the student team presentation that describes the test data, the improvements to the prototype, and its final cost.

Evaluate

Debriefing Questions

1. How did the data from our test represent the criteria and the constraints of the challenge?
2. What areas of our lunar water filter need to be improved based on the test data?
3. What were the reasons for the lunar water filter's failure during the tests?

Online Resource

"NASA STEM Cleaning Water Demonstration" is an excellent video to show students after they have constructed and tested their filters. Facilitators may want to watch it prior to the Prototype phase. There are several good ideas on how to build the filter container and the filter stand along with ideas for filtration materials. https://www.youtube.com/watch?v=mRfzyTIS_gg

STEM Career Connections

The video "NASA STEM All Stars" will introduce students to a variety of STEM careers and the people who are currently working at NASA in those fields, including a look at their backgrounds and job responsibilities. https://y4y.ed.gov/stemchallenge/nasa/frequently-asked-questions-and-help-desk-information

Accommodation

Students can be encouraged to test only one criterion or constraint at a time in order to focus on their water filter's success and improvements.

Challenge Connections

Student teams can take an in-person or virtual field trip to a water treatment plant to discover how water is treated, tested, and recycled back to the local community. STEM professionals from the local community can be interviewed or can offer water testing solutions that may be incorporated into students' lunar water filtration systems.

Communicate, Explain, and Share

For the final phase of the challenge, student teams will construct a student team presentation that documents and describes their progress through the engineering design process (EDP) to the final solution. Using scripts, photographs, and video clips, students will develop a final presentation that involves all the team members.

Objectives

Student teams will

1. Communicate, explain, and share the reasons for the team's decisions, research, and improvements to their prototype.
2. Communicate complex ideas clearly and effectively through a variety of digital platforms.
3. Creatively develop, implement, and communicate new ideas to others effectively.

"I Can" Statements

1. I can communicate, explain, and share the reasons for our team's decisions, research, and improvements.
2. I can communicate my team's ideas clearly through various digital means.
3. I can creatively communicate our team's ideas to others.

Preparation

Facilitators will identify the best software platforms that will allow students to assemble and edit their team presentations.

Engage

Guiding Questions

1. How will our team communicate, explain, and share our team's decisions, research, and improvements?
2. How can the team use digital technology to represent and describe their solution to the challenge?

Explore

Instructional Procedures

1. Students will begin by gathering the Student Journal pages where they completed their scripts during each phase of the EDP.
2. Using the most appropriate software platform, student teams will assemble, edit, and produce a team presentation that best describes their journey through each phase of the engineering design process.
3. During the team presentations, students will describe the problems they encountered and the improvements they made to their lunar water filter.

Explain (Cause and Effect)

During the student team presentation, students will explain their final solution to the challenge. In the discussion, students will need to explain the causes that led to each failure in the filter's design. Using the conclusions from the test data, students can describe the improvements the team made to their prototype that led to a successful solution.

Elaborate

The following suggestions can be used to creatively describe the team's journey through the engineering design process:

1. Photos with voice narration
2. Video with voiceover descriptions

Evaluate

Debriefing Questions

1. How can we communicate, explain, and share the reasons for the team's decisions, research, and improvements?
2. How were complex ideas communicated clearly through digital means?
3. How was the technology used to describe the team's progress through the engineering design process?

Online Resource

The video "NASA STEM Challenges: Telling Your Story" describes how to record a team presentation and includes lots of tips on how to use cameras and technology. Students will be able to apply much of the information as they tell their own stories throughout the EDP. https://y4y.ed.gov/stemchallenge/nasa/frequently-asked-questions-and-help-desk-information.

STEM Career Connections

Videographer is a STEM career that involves capturing data. A videographer can record a team's journey through the EDP. Student teams can express their creativity in designing and producing their team presentations as they explore video software and production platforms.

Accommodations

Student teams can create a slide presentation or trifold display that describes their team's progress through each phase of the EDP.

Challenge Connections

The team can sponsor a "Challenge Premiere Night" for local STEM professionals to view the student team presentation. The presentation can include an opportunity for students to ask questions about STEM careers.

Student Team Presentation Guidelines

For the final stage of the challenge, students will document their progress in a student team presentation to share with other student groups.

Student team presentations must meet the following guidelines:

1. The introduction must include the following: "This is team (team name) and we worked on the (name of challenge). The title of our presentation is (presentation title)."
2. For safety reasons, do not include names of students, teachers, school, city, or state in the introduction.
3. Using the presentation scripts, the presentation should document the team's progress through each phase of the engineering design process.
4. Student teams must describe the results of their research, including the STEM careers they explored and any information gathered from NASA scientists or engineers that helped them with their prototype design and testing.
5. During the presentation, students must explain how their lunar water filter met each of the criteria and constraints of the challenge.
6. Include the final cost of the prototype.
7. Describe the lunar water filter.
8. The total length of the presentation must not exceed 5 minutes.
9. Every student must be included in the presentation.

Culminating Event Team Questions

In preparation for the State Culminating Event, student teams may want to formulate answers to potential questions that may be posed by NASA scientists, engineers, and guests attending the event:

1. What did you discover through your research and testing that made the most impact on your prototype design?
2. What specific problems did your team have to address when designing, building, or testing your prototype?
3. Based on your findings, what would you recommend to a NASA scientist or engineer who is designing a lunar water filtration system and method to recycle water?
4. What was the greatest challenge your team had to overcome?
5. What STEM career did you find most interesting?
6. What did you learn about working together as a team?
7. How would your lunar water filter benefit the water filter systems on Earth?

Team Presentation Rubric

Student name_____ Team name _____

Communicate, Explain, and Share

The Team Presentation Rubric will be used to evaluate the student team presentations (video, student presentation, and/or slide presentation).

1. In the introduction, the team name, the challenge name, and the title of the presentation were all included. Personal or identifying information was NOT given in the introduction.

0	1	2	3	4	5
Not included	Needs improvement	Below average	Average	Above average	Excellent

2. The team explained the challenge, including the criteria and the constraints.

0	1	2	3	4	5
Not included	Needs improvement	Below average	Average	Above average	Excellent

3. The team described the results of their research, including the STEM career they explored and the information they collected from the virtual connection with the NASA scientist or engineer.

0	1	2	3	4	5
Not included	Needs improvement	Below average	Average	Above average	Excellent

4. The team explained how they used the engineering design process to design and construct their final prototype or model.

0	1	2	3	4	5
Not included	Needs improvement	Below average	Average	Above average	Excellent

5. As a conclusion, the team described the challenges and successes they experienced as they built, tested, and improved their prototype or model.

0	1	2	3	4	5
Not included	Needs improvement	Below average	Average	Above average	Excellent

Comments and Encouragement

Student Journal

Lunar Water Challenge

Add your Mission Patch

Name _____

Team name _____

Team Building

Student name _____ Team name _____

Directions: As a team, decide on a team name, design a mission patch, and create a team motto.

Team Name

Team Motto

Team Patch

NASA Mission Background

Student name _____ Team name _____

KWL Chart: What is NASA?

The National Aeronautics and Space Administration (NASA) was formed in 1958. Today there are 10 NASA centers located all around the country. From the first Mercury missions to the current Artemis program, NASA has explored and traveled into space. A return to the Moon is planned for 2024, and the next destination is Mars. The history of NASA includes many achievements that have led to engineering marvels and technological advancements. NASA history and information can be found at https://www.nasa.gov/content/nasa-history-overview and www.NASA.gov.

The NASA logo represents aspects of NASA's mission: space exploration (stars), aeronautics (red wing), and space travel (white circle).

What do aeronautical engineers do? Do an internet search and use the KWL chart to describe this career.

KWL Chart: What are the physical characteristics of the Moon?

The Moon has many different physical characteristics as compared to Earth. It is located about 384,000 km from Earth and revolves in a 27-Earth-day orbit. The Moon rotates on its axis and has a lunar day equal to 27 Earth days, or about 350 Earth hours long, as compared to the 24-hour day on Earth. Unlike Earth, the Moon does not have an atmosphere that regulates its temperature. Because of the long hours of sunlight and darkness and a lack of atmospheric conditions, the surface temperature of the Moon can range from about 123 °C during the day to –232 °C during the night. There is also no water cycle on the Moon. For more information about the Moon, visit www.NASA.gov or https://solarsystem.nasa.gov/moons/earths-moon/overview/.

Because of the rotation of the Moon, the back side of the Moon has only been seen by orbiting satellites and astronauts.

STEM Investigation: Science—What Is pH?

Student name _____ Team name _____

Directions: With your team, investigate the pH scale. Use litmus paper to determine the pH level of drinking water and other liquids.

Step 1

1. Locate a pH scale by doing an image search on the internet.

_____

_____

2. What is the difference between a base, a neutral, and an acid?

_____

_____

Step 2

Using litmus paper, test a variety of liquids and record the results in the table.

Liquid	pH measurement	Base, neutral, or acid
Drinking water		
Orange juice		
Laundry soap		

Discussion Questions

1. How is the pH level of safe drinking water measured and determined?

_____

_____

2. Why would drinking water that tests as an acid or a base be harmful to drink?

_____

_____

STEM Investigation: Math—How Long Does It Take Water To Drain Out of Sand?

Student name_____ Team name _____

Directions: Water on the Moon is frozen in the regolith, or lunar soil. As a team, set up an investigation to collect and analyze data that will determine the amount of time needed to drain the liquid water out of the soil.

Step 1

1. In a plastic container filled with sand, freeze 250 mL of water.
2. Engineer a stand that will hold the container filled with sand in an inverted position.
3. Under the container, place a layer of coffee filters that will catch any sand from the container as it thaws.
4. Place a graduated cylinder under the stand to catch and measure any liquid water.

Step 2

Record the time and water measurement data in the table below.

Time	Water, mL	Time	Water, mL

Step 3

Make a line graph that will display your data.

Graph name:_____

Discussion Question

What did you discover from your data?

_____

_____

STEM Investigation: Technology—How Do I Use a Spreadsheet?

Student name _____ Team name _____

Directions: It is extremely important that scientists and engineers have electronic tools to help them collect and analyze data throughout the engineering design process. A spreadsheet can be an extremely important piece of technology that organizes and displays data from investigations. In this STEM Investigation, you will have the opportunity to enter data and explore a spreadsheet.

Step 1

1. Open a spreadsheet on your computer using an application such as Microsoft® Excel®.
2. Locate the data from the "How Long Does It Take Water To Drain Out of Sand?" activity.
3. In the first row of your spreadsheet, place the two headings for the data: **Time, sec** (seconds) and **Water, mL** (milliliters). You may want to bold the headings.
4. Using the data, enter each of the time measurements and corresponding water measurements into the cells of the spreadsheet.
5. Many spreadsheet features are valuable to a scientist or an engineer when analyzing data. Spend some time exploring the spreadsheet.
6. Explore some of the many instructional videos on YouTube® that demonstrate how to use spreadsheets.

Step 2

Print out your spreadsheet and tape it here:

Tape spreadsheet here

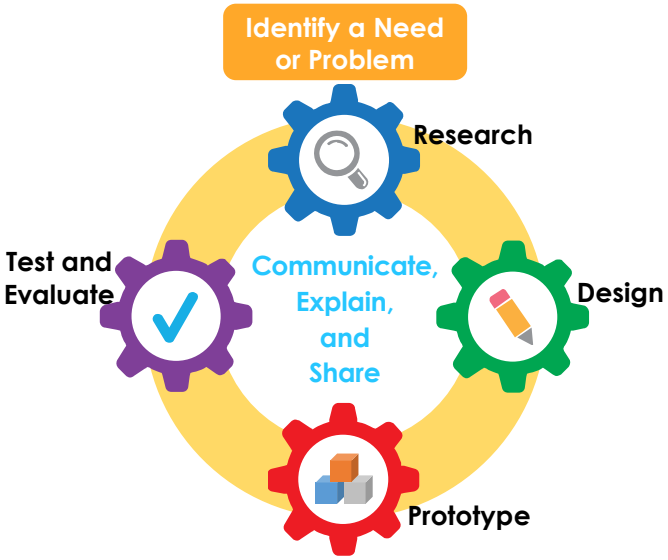
Discussion Question

Why is a spreadsheet an important tool to use when collecting and analyzing data?

_____

_____

Engineering Design Process



Engineering design process prototype. Prototype and accompanying text adapted from 2016 Massachusetts Science and Technology/Engineering Curriculum Framework, Massachusetts Department of Elementary and Secondary Education, http://www.doe.mass.edu/frameworks/scitech/2016-04.pdf.

Identify a Need or Problem

How can we engineer a solution by designing, building, testing, and improving a prototype that will meet the criteria and constraints of the NASA challenge?

Research

During the Research phase, our team will locate the answers to our questions by exploring the internet, delving into NASA resources, and interviewing a NASA scientist or engineer.

Design

In the Design phase, our team will draw a prototype that could solve the challenge. Team members will combine their ideas and designs into one team drawing that will meet all the criteria and constraints of the NASA challenge.

Prototype

Throughout the Prototype phase, our team will work collaboratively to construct our proposed prototype according to our drawing.

Test and Evaluate

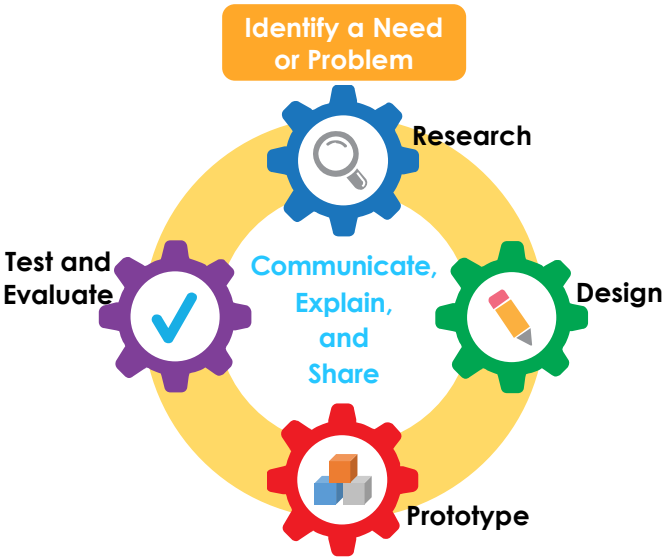
In the Test and Evaluate phase, our prototype will be subjected to tests to determine its ability to meet all the criteria and constraints of the NASA challenge. From each of the tests, our team will gather and evaluate our data to improve the design of our prototype.

Communicate, Explain, and Share

During each phase, our team will record and share our progress through the engineering design process (EDP). Our team will communicate our design solutions, share our ideas with others, and explain each phase of the EDP.

Engineering Design Process Questions

Student name _____ Team name _____



Engineering design process prototype. Prototype and accompanying text adapted from 2016 Massachusetts Science and Technology/Engineering Curriculum Framework, Massachusetts Department of Elementary and Secondary Education, http://www.doe.mass.edu/frameworks/scitech/2016-04.pdf.

Answer the following questions:

1. Why is it important to follow the engineering design process (EDP) when solving a challenge?

_____

_____

2. How has NASA used the EDP to explore the Moon?

_____

_____

3. Which STEM career do you find the most interesting?

_____

_____

4. What have you discovered about this STEM career from your internet search?

_____

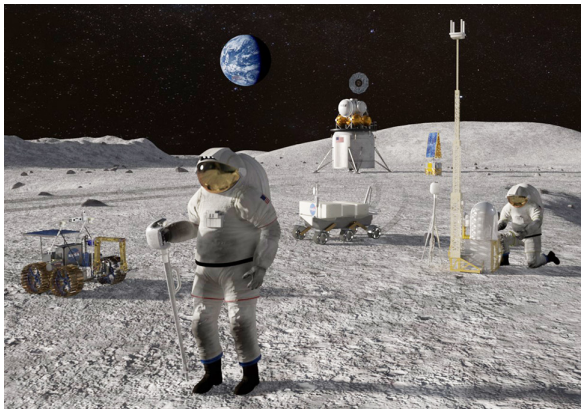
_____

Identify a Need or Problem: Lunar Water

Student name_____ Team name _____

Identify a Need or Problem

Scenario



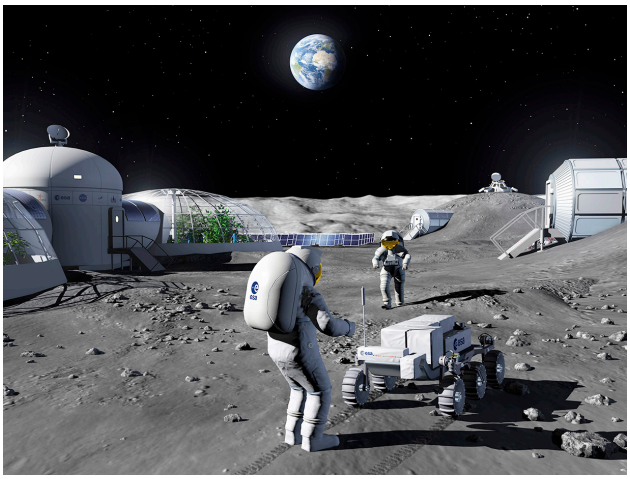
Artist's concept of astronauts walking on the Moon's surface during an Artemis mission. (NASA)

While living on the Moon, it is essential that the water consumed in the lunar habitat is recycled, purified, and reused. Because of the limited-weight requirements to ship cargo on the Space Launch System (SLS) and Orion spacecraft, the amount of water that can be transported and supplied for long-term missions must be precisely calculated.

All the water used by the astronauts on the International Space Station (ISS) is recycled, purified, and returned back into the ISS water systems. In a space habitat, this wastewater—also known as gray water—includes moisture exhaled by the astronauts, sweat from their workouts, and water from food preparation, shaving, and the bathroom shower.

During the Artemis program, the gray water will be recycled, purified, and reused both on the Gateway and in the lunar habitat. For the lunar crew living and working on the Moon, the purified water must have a pH range of 6.0 to 8.5 and be clear of all debris. It should also be odorless.

Lunar Water Challenge



Artist's impression of a multidome lunar base, based on a three-dimensional (3D) printing concept. Robots will cover the inflated domes with a layer of 3D-printed lunar regolith to help protect occupants against space radiation and micrometeoroids. (ESA, P. Carril)

The Lunar Water Challenge question is this: How can gray water be recycled, purified, and reused so that it can sustain our astronauts in the lunar habitat?

The challenge is for each team to design, develop, and test a water filter that will recycle, repurpose, and transform gray wastewater into purified drinking water for the lunar habitat.

To begin, each team will need to develop a water filter that consists of both a container and filtering material that will clean the pollutants and contaminants out of the water. The water filter will have an opening where the gray water is poured into the filter. Once the gray water has drained through the filter, the purified water will be collected in a graduated cylinder.

The second part of the Lunar Water Challenge will address the filtration materials themselves. Unlike on Earth, the used filter material cannot be distributed or buried. Each team will provide recommendations or suggestions describing the safest way to process the used filter material, which now contains contaminants that have been separated from the water.

Challenge Guidelines

Identify a Need or Problem

Student teams will

1. Gather and record test data that describes both the clean water (bottled drinking water) and the gray water (four parts water and one part Italian salad dressing). Record pH levels and observations on odor, debris, and contaminants.
2. Measure and record the mass of the filtration materials used in the water filter in grams (g).
3. Using a graduated cylinder, measure and record the following:
   a. Amount of gray water to be poured into the filter
   b. Amount of water that drains out of the filter

This is just one example of a lunar water container that could hold the filtration materials.

4. With a timer, measure and record the amount of time it takes the gray water to seep through the filter.
5. Once the water filtration process is complete, develop a disposal plan that includes suggestions on how to safely dispose of the filtration material without dispersing it on the lunar surface.

Challenge Criteria

Develop a water filter that will clean 250 mL of gray water as determined by the following four tests:

1. pH Scale Test: The pH of the filtered water must measure as neutral (between 6.5 and 7).
2. Debris Test: The filtered water must be observed as clear, with no floating debris.
3. Odor Test: The filtered water must not smell like Italian salad dressing.
4. Contaminants Test: All pollutants and contaminants that were in the gray water must be removed by the filter.

Challenge Constraints

1. The filter must process 250 mL of water.
2. The mass of the filtration materials (up to three different types) together with the container must not exceed 1,000 g of mass.
3. The graduated cylinder used to collect the discharged water draining through the filter must be large enough to accommodate the filtered water.

Introductory Video

Identify a Need or Problem

Student name_____ Team name _____

Directions: With your team, watch the introductory video. Identify information about the challenge, including what your prototype MUST DO and what it MUST NOT do (criteria and constraints).

Using your own words, restate the problem:

How can we design a	Our prototype will

What information did you discover from the introductory video regarding the Lunar Water Challenge and water on the Moon?

1. _____

_____

_____

_____

2. _____

_____

_____

3. _____

_____

_____

4. _____

_____

_____

5. _____

_____

_____

Discussion Questions

Identify a Need or Problem

Student name_____ Team name _____

Directions: Answer the following discussion questions.

1. How are the Earth and the Moon similar? How are they different?

_____

_____

_____

2. How will the lack of a water cycle on the Moon impact the lunar crew?

_____

_____

_____

3. Why must the disposal of the filter material be considered in the design?

_____

_____

_____

Student Team Presentation Script: Introduction

Directions: Write an introduction to your presentation that describes your team and the challenge (1 minute).

"This is team (team name), and we worked on the (name of challenge). The title of our presentation is (presentation title)."

_____

_____

_____

_____

_____

_____

Research

KWL Chart

Student name_____ Team name _____

Directions: After reading the challenge and watching the introductory video, complete the KWL chart with your team.

KWL Chart: Research

What do we know?	What do we need to know?	What did we learn?

Research Discussion Questions

Student name_____ Team name _____

Directions: Answer the following discussion questions.

1. How is water recycled in my city or region?

_____

_____

2. How are impurities, pollution, and bacteria removed from my drinking water?

_____

_____

3. How is water recycled on the International Space Station?

_____

_____

_____

_____

Student Team Presentation Script: Research

Write a script for your presentation that describes your discoveries. Your script should be under 1 minute.

Describe what your team discovered during the Research phase.

_____

_____

_____

_____

_____

_____

_____

NASA Virtual Connection: KWL Chart

Student name_____ Team name _____

Directions: Complete the following KWL chart during your virtual connection with a NASA scientist or engineer.

KWL Chart: Virtual Connection

What do we know?	What do we need to know?	What did we learn?

NASA Virtual Connection Questions

Student name_____ Team name _____

Directions: Complete the following questions after your connection with a NASA scientist or engineer.

1. What is the name of the scientist or engineer? At which NASA center is the scientist or engineer located?

_____

2. What kind of scientist or engineer did your team talk to? What is the person's role at NASA?

_____

3. What advice did the scientist or engineer offer to your team?

_____

Student Team Presentation Script: Research Phase

Directions: Describe what your team discovered during the Research phase. (1 minute)

Which STEM career did you find most interesting?

_____

_____

_____

What did you discover when you talked with the NASA scientist or engineer?

_____

_____

_____

_____

Design

Individual Design

Student name_____ Team name _____

Directions: Sketch your initial design in the space below and label each part of your drawing.

How does your drawing represent the criteria and the constraints of the challenge?

1. _____

2. _____

Choosing the Best Designs

Student name_____ Team name _____

Directions: As a team, discuss each member's final drawing using the table below. The most promising solution should include elements from more than one design. Remember to include all the criteria and constraints of the challenge.

Designer name	Does this design meet the criteria and constraints of the challenge?	What are the strongest elements of this design?
1		
2		
3		
4		

Team Design

Student name_____ Team name _____

Directions: Choose the best ideas from each team member and create a team design of the prototype.

Answer the following discussion questions.

1. What filtration materials do you think will be the best to use for each layer?

_____

_____

2. What contaminant do you predict each layer of your filter will clean out of the gray water?

_____

_____

3. Explain how your filter meets the criteria and constraints of the challenge.

_____

_____

_____

_____

Approved by: _____

Student Team Presentation Script: Team Design

Student name_____ Team name _____

Directions: Write a paragraph for your team presentation script that describes your team design. For this section, your script should be no longer than 1 minute.

How does your design meet the criteria and the constraints of the challenge?

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Prototype

Student name _____ Team name _____

Directions: Using the materials provided, build a prototype based on your team design. Make sure your team's prototype meets all the criteria and constraints of the challenge.

Which part of the build will each team member be responsible for?

	Engineer	Accountant	Videographer	Manager
Team member's name				

Construction Checklist

	Filtration materials (up to three types)	Filter can process 250 mL of gray water	Filter and container do not exceed 1,000 g	Gray water (4 parts water, 1 part Italian dressing)	Graduated cylinder for final water collection
Describe your prototype					

Answer the following discussion questions.

1. In what ways did we work together, collaboratively as a team, to build our prototype?

_____

_____

2. Why did you choose the specific filtration materials?

_____

_____

3. Explain the construction decisions your team made while building your prototype.

_____

_____

4. How does your prototype meet the criteria and constraints of the challenge?

_____

_____

Student Team Presentation Script: Prototype

Student name_____ Team name _____

Write a paragraph describing how your team constructed your prototype. Your script should be no longer than 1 minute.

How did your prototype meet the criteria and constraints of the challenge?

Budget Worksheet

Student name_____ Team name _____

Directions: The accountant on your team will complete the Budget Worksheet. In the table, record all the materials your team used in the build, the individual unit cost, and the quantity needed to complete your prototype. In the last column, calculate the total for each item in order to determine the total cost of your prototype.

	Material	Unit cost	Quantity	Total
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
			Total cost:	

Test and Evaluate

Student name _____ Team name _____

Data Collection Sheet

Directions: Begin by collecting data on 250 mL of bottled water and 250 mL of gray water before it is poured into the filter. Record your observations and data in the chart.

Gray Water and Bottled Water: Unfiltered Data

Water type	Mass of water, g	pH scale test (litmus paper)	Debris test (floating debris)	Odor test (detection of salad dressing)	Contaminants test (pollutants and oils present; water clear or cloudy)
Bottled water (250 mL)					
Gray water (250 mL)					

Directions: As a team, conduct the first test of your water filter using up to three different filtration materials. Using a stopwatch, time and record how long the water takes to drain through the filter. In the chart below, observe and record how the filtration materials remove the contamination.

Filtered Gray Water Data Chart: Test 1

Material (up to three)	Mass of filter, g	Time to drain through filter, sec	pH scale test (litmus paper)	Debris test (floating debris)	Odor test (detection of salad dressing)	Contaminants test (pollutants and oils present; water clear or cloudy)
1. 2. 3.						

Using the results from Test 1, how would you improve your filter?

_____

_____

_____

Directions: As a team, conduct the second and third tests with your water filter using different filtration materials (or a different combination of materials) than you used in Test 1. Using a stopwatch, time and record how long the water takes to drain through the filter. Observe and record in the charts below how the filtration materials remove the contamination.

Filtered Gray Water Data Chart: Test 2

Material (up to three)	Mass of filter, g	Time to drain through filter, sec	pH scale test (litmus paper)	Debris test (floating debris)	Odor test (detection of salad dressing)	Contaminants test (pollutants and oils present; water clear or cloudy)
1. 2. 3.						

Using the results from Test 2, how would you improve your filter?

_____

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Filtered Gray Water Data Chart: Test 3

Material (up to three)	Mass of filter, g	Time to drain through filter, sec	pH scale test (litmus paper)	Debris test (floating debris)	Odor test (detection of salad dressing)	Contaminants test (pollutants and oils present; water clear or cloudy)
1. 2. 3.						

1. Using the results from Test 3, how would you improve your filter?

_____

_____

_____

2. What combination of filtration materials best recycled the gray water? Why?

_____

_____

Time Tests

Student name_____ Team name _____

Directions: Use the Time Chart below to record the time it took for 250 mL of gray water to drain through your filter during Tests 1, 2, and 3. Also list the filtration materials that were included in the filter used for each test.

Time Chart

Test	Filtration material	Time to drain through filter, seconds
1		
2		
3		

Directions: In the chart below, construct a line graph that represents the time data. Along the bottom of the graph (x-axis), include the name of each test (Test 1, Test 2, and Test 3). On the left side of the graph (y-axis), include the time results. Draw the corresponding plot points for each of the three tests. Complete the graph by connecting the points with a line.

Graph name: _____

Filtration Material Disposal

Student name _____ Team name _____

Directions: In the box below, provide a recommendation on how to best dispose of, recycle, or reuse the filtration material from the lunar water filter. Dispersing it on the lunar surface is not an option. Include your recommendation in your team presentation.

Our team recommends that the best process to dispose of the filtration material in the lunar habitat is:

_____

_____

_____

_____

_____

Student Team Presentation Script: Test and Evaluate

Directions: Write a paragraph describing your team's most successful lunar water filter. Make your script no longer than 1 minute.

How did your lunar water filter solve the challenge? What were the strengths, and what were the concerns? What suggestions does your team have for future engineers who would like to solve this challenge?

_____

_____

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_____

_____

Communicate, Explain, and Share

Student name_____ Team name _____

Student Team Presentation Script: Communicate, Explain, and Share

Write a paragraph describing your team's final lunar water filter. This script should be no more than 1 minute.

What are your team's final thoughts regarding the challenge?

_____

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Team Presentation Organizer

Communicate, Explain, and Share

Student name _____ Team name _____

The final stage of the challenge is to communicate the team's progress through each phase of the engineering design process (EDP). The team's journey must be documented using a student team presentation. The finished presentation must meet the guidelines in the following checklist.

Presentation Guidelines	Checkbox
1. The introduction must include the following: "This is team (team name) and we worked on the (name of challenge). The title of our presentation is (presentation title)."	
2. For safety reasons, do not include names of students, teachers, school, city, or state in the introduction.	
3. Using the presentation scripts, the presentation should document the team's progress through each phase of the engineering design process.	
4. Student teams must describe the results of their research, including the STEM careers they explored and any information gathered from NASA scientists or engineers that helped them with their prototype design and testing.	
5. During the presentation, students must explain how their lunar water filter met each of the criteria and constraints of the challenge.	
6. Include the final cost of the prototype.	
7. Describe the lunar water filter.	
8. The total length of the presentation must not exceed 5 minutes.	
9. Every student must be included in the presentation.	

Team Presentation Rubric

Student name _____ Team name _____

Communicate, Explain, and Share

The Team Presentation Rubric will be used to evaluate the student team presentations (video, student presentation, and/or slide presentation).

1. In the introduction, the team name, the challenge name, and the title of the presentation were all included. Personal or identifying information was NOT given in the introduction.

0	1	2	3	4	5
Not included	Needs improvement	Below average	Average	Above average	Excellent

2. The team explained the challenge, including the criteria and the constraints.

0	1	2	3	4	5
Not included	Needs improvement	Below average	Average	Above average	Excellent

3. The team described the results of their research, including the STEM career they explored and the information they collected from the virtual connection with the NASA scientist or engineer.

0	1	2	3	4	5
Not included	Needs improvement	Below average	Average	Above average	Excellent

4. The team explained how they used the engineering design process to design and construct their final prototype or model.

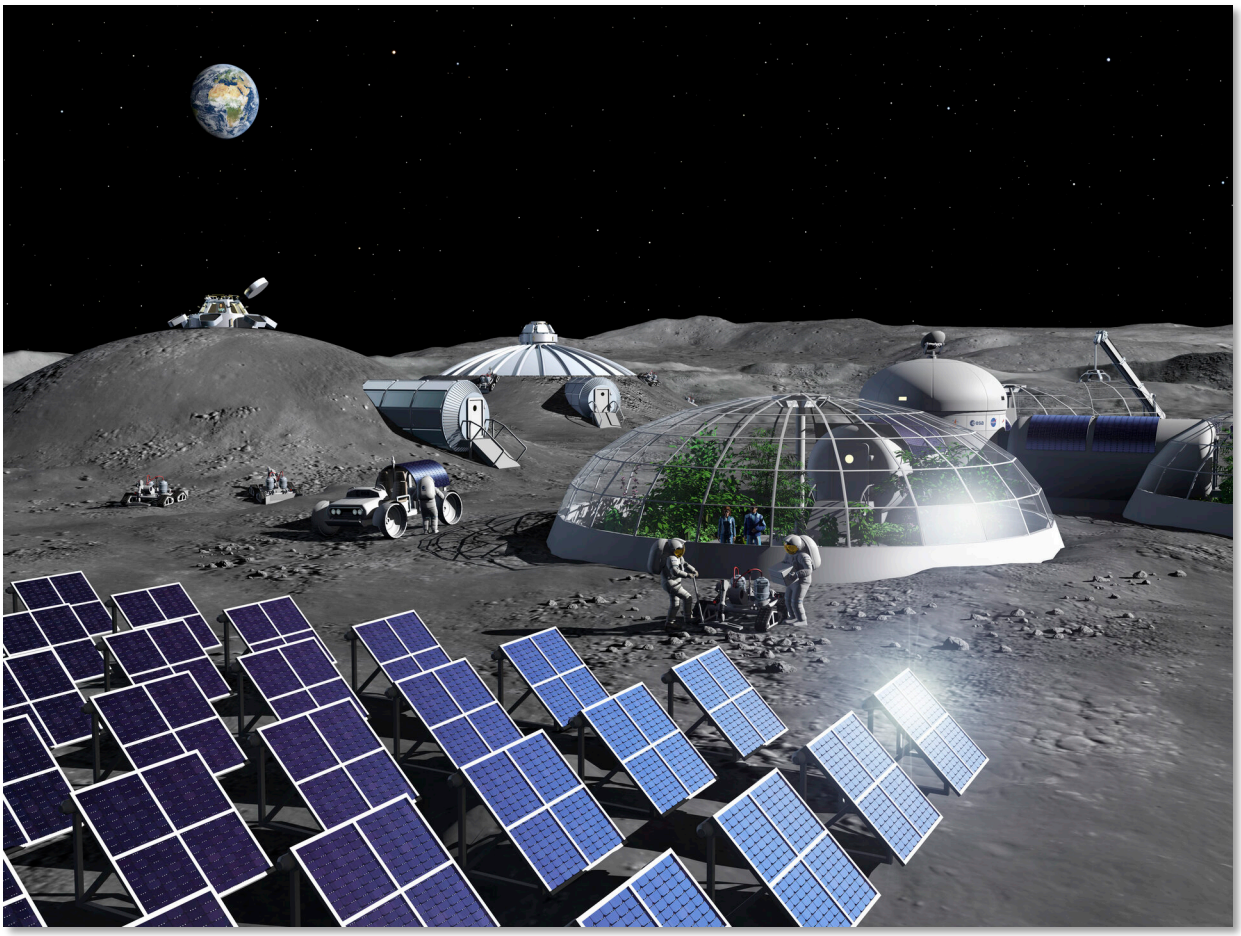
0	1	2	3	4	5
Not included	Needs improvement	Below average	Average	Above average	Excellent

5. As a conclusion, the team described the challenges and successes they experienced as they built, tested, and improved their prototype or model.

0	1	2	3	4	5
Not included	Needs improvement	Below average	Average	Above average	Excellent

Comments and Encouragement

Back cover: Artist's impression of a multidome lunar base. (ESA/P. Carril)



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