Introductory Materials

Standards Addressed

Next Generation Science Standards

Science and Engineering Practices

1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using math and computational thinking
6. Constructing explanations and designing solutions
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

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.

ISTE NETS and Performance Indicators for Students

Critical thinking, problem solving, and decision making

a. Identify and define authentic problems and significant questions for investigation
b. Plan and manage activities to develop a solution or complete a project
c. Collect and analyze data to identify solutions and/or make informed decisions
d. Use multiple processes and diverse perspectives to explore alternative solutions

The Engineering Design Challenge

Background

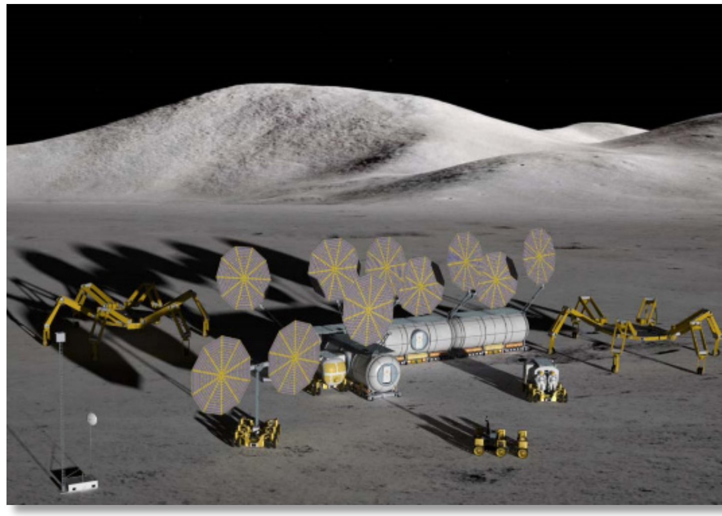


Figure 1.—Artist's concept of a potential lunar outpost (NASA)

Future astronaut crews will need to learn how to grow safe, edible, and nutritious plants while living and working in space during long-duration missions. The lunar environment is so extreme that astronauts or plants are not able to live on the lunar surface without a protective habitat. Because of the extreme environment, the lunar habitat must provide the plants with light, water, and atmosphere. All the essential supplies and materials needed to survive on the Moon will be stowed on a rocket, shipped to the Moon, and deployed on the surface. There is a limited amount of space available on the rocket for the large amount of needed lunar cargo. The mass and the volume of the stowed cargo must be closely monitored for fuel efficiency and the limited storage on the rocket.

The Challenge

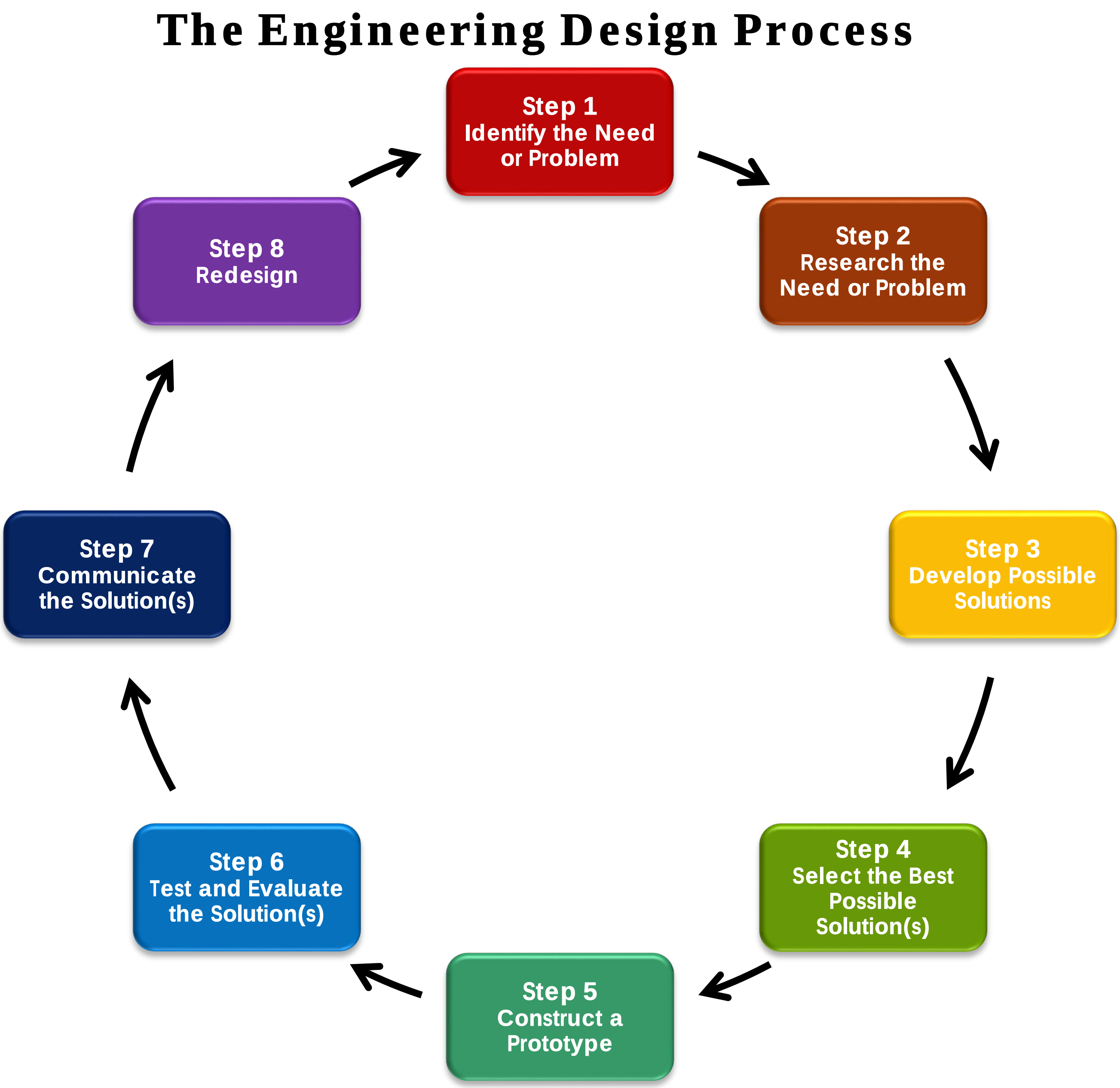
You and your team will have the task of engineering a tabletop model of a plant growth chamber that can be folded, stowed, and shipped on a rocket destined for the Moon. When the shipment arrives, the future lunar astronauts will then be able to expand the plant growth chamber and deploy it on the lunar surface. Because this project is in the development stage, the team will only need to design, build, and present a tabletop model of the plant growth chamber rather than a full sized, lunar structure that is designed to grow enough food for the entire lunar crew.

Criteria and Constraints

The plant growth chamber must meet the following criteria and constraints:

1. On the rocket, the plant growth chamber model must **not exceed** a mass of 50 grams and a stowed volume of 1000 cm^3.
2. The deployed plant growth chamber can be any shape, however, the volume cannot exceed 1,000,000 cm^3.
3. The deployed plant growth chamber may or may not be connected to the lunar habitat, but it must have a way for the astronauts to have access to the chamber.
4. The model plant growth chamber must use a system of expansion from its stowed shipment package on the rocket to its final deployed structure on the Moon.

Student teams will follow the eight steps in the EDP to complete the challenge.



This Engineering Design Process model was adapted from the Massachusetts Science and Technology/Engineering Curriculum Framework (published October 2006, http://www.doe.mass.edu/frameworks/scitech/1006.pdf).

The Engineering Design Process

STEP 1: Identify the Need or Problem.—Working in teams, students state the problem in their own words.

STEP 2: Research the Need or Problem. —Teams use resources, from the Internet, the library, or discussions with subject matter experts (SMEs), to examine how this problem is currently being solved or how similar problems are being solved.

STEP 3: Develop Possible Solutions.—Team members draw on their mathematic and scientific knowledge to brainstorm all the possible ways that they might solve the problem. They choose the most promising options and refine their solution by quickly sketching in two or three dimensions. Labels and arrows should be included to identify parts.

STEP 4: Select the Best Possible Solution(s).—Team members share their ideas and answer questions from the other team members. Each team discusses and records strengths and weaknesses from each design. They determine which solutions best meets the original need or solves the original problem, possibly including features from more than one design. The team writes a statement that describes why they chose the solution.

STEP 5: Construct a Prototype.—Team members construct a full-size or scale model of the selected solutions in two or three dimensions. The educator helps to identify and acquire appropriate modeling materials and tools.

STEP 6: Test and Evaluate the Solution(s).—Teams test their prototypes to determine how effectively they solved the need or problem. Data are collected to serve as evidence of their success or need for improvement.

STEP 7: Communicate the Solution(s).—Team members record and share what they learned about their design based on testing. Teams make a presentation that includes how their solution(s) best solved the need or problem and any improvements that could be made. They could ask students from other teams to review the solution and help identify changes.

STEP 8: Redesign.—Team members consider modifications to their solution(s) based on the information gathered during the tests and presentation. Teams review the original need or problem to ensure their modifications still meet the necessary criteria and constraints, and restart the EDP cycle.

Pacing Guide

The engineering design challenge (EDC) must be completed by students within the designated time frame. You are encouraged to adjust the pace to meet your student needs and learning environment. Visit the NASA STEM challenges Web site (http://y4y.ed.gov/stemchallenges/nasa) for a list of important challenge dates and submission deadlines.

We estimate the total instructional time needed to complete the entire challenge will be between 20 and 35 hours and approximately 3 hours of instructional time will be required to complete the activities listed for each week. The engineering design process (EDP) is cyclical. Feel free to structure the sessions to fit your needs based on your students and available time. You should establish a schedule that is flexible enough to allow your students to move from step to step as needed. It is possible that teams may need to loop back to an earlier step and rework their designs. The following table can be used as a guide for implementation. Activities may take more or less time depending on student readiness and depth of inquiry.

EDC Week	EDP Step	Actions
Pre-Challenge	Pre-EDP	Attend training and order materials
Week 1	Step 1 Step 2	Identify the Need or Problem Research the Need or Problem
Week 2	Step 2 Step 3	Research the Need or Problem Develop Possible Solutions
Week 3	Step 3 Step 4	Develop Possible Solutions Select the Best Solution
Week 4	Step 5 Step 6	Construct a Prototype Test and Evaluate the Solutions
Week 5	Step 7 Step 8 Step 5	Communicate Solutions Redesign Rebuild
Week 6	Step 5 Step 6	Rebuild Test and Evaluate Solution
Week 7	Step 7 Step 8	Communicate Solutions (compare iterations) Redesign (recommendations for the future)
Week 8	Post-EDP	Create and upload student videos

Challenge Checklist

Prior to the Challenge

Things to download, print, review, and copy.

- ❑ 1. Download and review the presentation slides for students.
- ❑ 2. Download, print, and review the Video Criteria and Rubric. Make a copy for each team of students.
- ❑ 3. Download, print, and review the Educator Guide, Packing Up for the Moon. Print the Student Journals for each team.
- ❑ 4. Download or bookmark the introductory video “Telling Our Story with Video” and any other videos needed for your presentation.
- ❑ 5. Download and review the Technical Requirements for the Video Production Page.
- ❑ 6. Download, review, and print enough media release forms for each student.

Things to schedule, set up, or test.

- ❑ 1. Review the online Event Schedule and select at least one live event for students to interact with a NASA subject matter expert.
- ❑ 2. Gather and organize materials from the materials list for each activity.
- ❑ 3. Test your technology setup to make sure students can see and hear videos, slides, etc.
- ❑ 4. Identify a testing area or testing table that will provide a space for the students to safely test their models and designs.
- ❑ 5. Check your video or digital cameras to ensure they are fully charged and have enough memory or tape for recording challenge activities.

During the Challenge

- ❑ 1. Distribute media release forms to each participating student and set a due date for return.
- ❑ 2. Ask each group of students to come up with a unique team name.
- ❑ 3. Use the presentation slides for students to lead the students through the challenge.
- ❑ 4. Encourage each team to take pictures and video throughout the challenge for use in their final video.
- ❑ 5. Help students prepare questions and information to share with NASA subject matter experts during the live event.
- ❑ 6. Participate in one or more live events.

After the Challenge

- ❑ 1. Review Video Criteria, Rubric, and “Telling Our Story with Video” with students.
- ❑ 2. Assist students as they plan and create their final video.
- ❑ 3. Upload student video submissions.
- ❑ 4. Allow enough time to send a separate email with entry information and media release forms for each video by ____________. Participate in evaluation of the 21CCLC program.

NASA Connection

NASA

Why We Explore

Humanity's interest in the heavens is universal and enduring. Humans are driven to explore the unknown, discover new worlds, push the boundaries of scientific and technical limits, and then push further. Society has benefited for centuries because of our desire to explore and challenge the boundaries of what we know.

Human space exploration helps to address fundamental questions about our place in the universe and the history of our solar system. By addressing the challenges related to human space exploration, we expand technology, create new industries, and help to connect peacefully with other nations. Curiosity and exploration are vital to the human spirit and accepting the challenge of going deeper into space we invite the citizens of the world today and the generations of tomorrow to join NASA on this exciting journey.

The United States is a world leader in the pursuit of new frontiers, discoveries, and knowledge. The National Aeronautics and Space Administration, more commonly known as NASA, has sent people to land on the Moon, sent spacecraft to the Sun and almost every planet in the solar system, and launched robotic explorers to travel beyond the solar system. NASA's vision is to reach for new heights and reveal the unknown for the benefit of humankind.

NASA was formed in 1958, and has a history of unique scientific and technological achievements in human space flight. From John Glenn's 1962 orbit around the Earth in *Mercury* Friendship 7 through the Apollo missions, the space shuttle years, to today's orbiting International Space Station (ISS), NASA is on the forefront of manned space flight. NASA's newest and most advanced human spacecraft, *Orion*, will usher in a new era of space exploration. *Orion* will serve as the exploration vehicle that will carry the crew to space, provide emergency abort capability, sustain the crew during space travel, and provide safe re-entry from deep space.

Orion was tested in December 2014 in a successful uncrewed orbital flight test. It will be launched on a heavy-lift cargo rocket, the Space Launch System (SLS), the most powerful rocket ever built. *Orion* will be sent to near-Earth asteroids, our own Moon, the moons of Mars, and eventually to Mars itself.

NASA's future success and global leadership will be determined primarily by the investments and innovations we make in scientific research, technology, and our workforce today. NASA's focus has always been, and will always be, to discover, invent, and demonstrate new technologies, tools, and techniques that will allow the United States to explore space while improving life on Earth.

STEM Careers at NASA

What is an engineer?

Engineers are at the heart of every engineering design challenge. Engineers are people who design and build things that we use every day. The following video will explain the role of an engineer and can be shared with your students. https://www.youtube.com/watch?v=wE-z_TJyzil. After viewing the video, ask the students to describe what an engineer does.

Figure 2.—Aerospace Engineer Chris Randall tests rocket parts and life support systems to ensure they work as planned. (NASA)

After viewing the video, have students discuss what they learned about what engineers do. **An engineer is a person who works on a team to solve a problem that humans want to solve or make better**. Examples of NASA-engineered products and services follow.

Figure 3.—Simulation System Engineer Debbie Martinez works on developing general aviation flight simulation software. (NASA)

- **Transportation**.—NASA engineers work with companies to design and develop aircraft that are safer, quieter, lighter, and more fuel efficient and reliable.
- **Public Safety**.—Environmental engineers at Johnson Space Center developed a new simplified version of a bacteria test that astronauts can use on the ISS. The same test is now being used to help rural communities monitor their water supplies for contamination. A software phone app has been developed to make this information public.
- **Consumer Goods**.—NASA engineers developed light-emitting diode (LED) lighting for life on the ISS. The LED lighting is used to stimulate energy and focus as well as help crew members relax. LED lighting is now used in numerous homes, hotels, and resorts.
- **Food processing control**.—NASA engineers worked with food production companies to create a process to identify the critical points where food could be contaminated.
- **Information Technology**.—NASA engineers worked with Massachusetts Institute of Technology (MIT) to develop a program that highlights the most reliable combinations of technologies for crewed missions to Mars. This program is now used to help homebuilders choose cost- and energy-efficient floor plans and materials.

It is important for young children to understand and to relate to what an engineer does to benefit and improve society. It is equally important to address misconceptions about who can be engineers. Men and women of all races, ethnicities, and walks of life choose to become engineers. Examples of this and NASA career profiles can be explored at https://www.nasa.gov/audience/forstudents/careers/profiles/index.html.

What is the engineering design process (EDP)?

A cycle of steps that teams of engineers use to guide them as they work to solve a problem. The EDP is a cycle that leads to the development of a new product or system. The cycle repeats and continuously refines and improves the product or system. During this challenge, students should complete each step and document their work as they develop and test their design. To do this, students need to perform each of the steps in the EDP and repeat the cycle, as often as time and resources allow, to develop the best end product. On repeat iterations of the cycle, some steps will only need to be briefly revisited to confirm that teams are still on track. Other steps will need to be completely redone.

Students who are new to the EDP will probably be introduced to unfamiliar concepts. Students may or may not have heard such words as “criteria” or “constraints,” which are commonly associated with engineering design. You may want to immerse students in the vocabulary and use simple explanations.

For example,

- **Criteria** are what your solution **must** do.
- **Constraints** are what your solution **must not** do.

Like the EDP, the significance of the words can be refined as students repeat the process and build a deeper understanding of what they are doing.

What is an engineering design challenge?

An educational activity that helps students understand the EDP by solving problems just like real engineers would. Students are presented with a challenge or problem and, using the EDP, work in teams to complete activities and experiments to develop solutions to the original problem. These challenges facilitate teamwork, problem solving, and brainstorming ideas like real-world engineers encounter.

Information for Educators

Challenge Background Information

Why is growing plants important to future lunar crews?

Studying how plants grow in space and how to produce food for the lunar crew will be necessary to sustain the astronauts during extended missions. Astronauts will require life-support capabilities and food production systems beyond what is now available. For plants to grow and produce food, they require clean water, nutrients in the soil, and an Earth-like atmosphere. During photosynthesis, plants remove carbon dioxide (CO_2) from the air while they produce oxygen (O_2) and food for the astronauts. At very high light intensities, plants such as wheat, would supply food and oxygen for one person in a small amount of space. At moderate light intensities, a diverse mixture of crops would supply a more complete diet for one person and meet all of their oxygen needs. Plants are also important for water regeneration on the spacecraft or habitat. Plant systems will be used to purify wastewater as water vapor is condensed to produce clean drinking water.

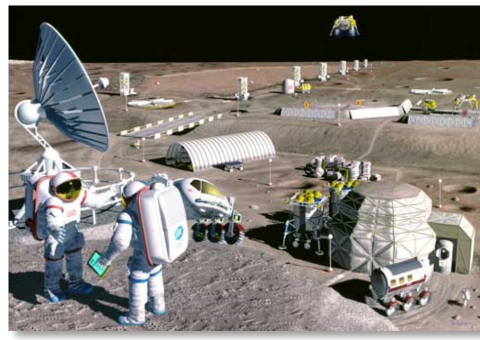


Figure 4.—Artist’s concept of a potential lunar outpost. (NASA)

Could plants grow in the lunar environment?

Plant species that are used to produce food to feed Earth’s population cannot grow in the extreme environment of the Moon. However, NASA scientists are currently developing plant growth chambers that will allow astronauts to grow plants on the Moon in the simulated environment of Earth. To accomplish this goal, the extreme lunar environment must be adapted in order for plants to survive. The lack of lunar atmosphere does not provide the necessary protection from the dangerous solar radiation or the temperature excesses found on the lunar surface. The lunar day and night cycle is so extreme that it will not allow the plants to properly engage in photosynthesis. Finally, the lack of fresh water and necessary nutrients found in the lunar soil will also prohibit the growth of plants. All of these environmental problems must be addressed in growth chambers before plants can be grown on the Moon.

Figure 5.—Artist’s concepts of plant growth chambers. (NASA)

How are plants affected by the low-gravity environment of the Moon?

Astronauts on long missions will need to grow their own food. One plant experiment on the International Space Station (ISS) has successfully grown a mustard plant from seed in 2 months. The low-gravity environment of the Moon affects virtually every aspect of plant growth. Answers to important questions about the basics of plant growth and development lie in the understanding of how gravity affects plant processes in the lunar environment. The more knowledge biologists gain from research about how a plant functions in extreme environments, the more that information can be applied to new research that will enhance life on Earth. Plant research results contribute to NASA's goals of furthering human exploration of space and improving the quality of life on Earth through applications in medicine, agriculture, biotechnology, and environmental management.

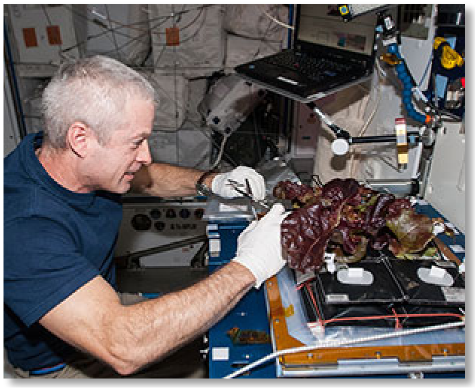


Figure 6.—ISS astronaut Steve Swanson harvesting red romaine lettuce grown from seed inside the station's Veggie facility in June 2014.

Figure 7.—NASA astronaut Doug Hurley, STS-135 pilot, moves around supplies and equipment.

How do you pack cargo onto the SLS?

America’s Space Launch System (SLS) is the new heavy-lift rocket that will be the largest launch vehicle ever built. The SLS will carry the Orion Multi-Purpose Crew Vehicle as well as important cargo, equipment, and science experiments into deep space. Cargo is packed on the rocket with specially designed cases. The 130-metric-ton (143-on) rocket will lift more than 286,000 pounds of payload and it will provide 20 percent more thrust than the Saturn V rocket. The SLS will stand 284 feet tall and weight 6.5 million pounds.

For more information visit

- Orbiting Agriculture—http://www.nasa.gov/missions/science/f_lada.html
- “Plants in Space” video—https://www.youtube.com/watch?v=iNangMq5wSQ
- Lunar Plant Growth Chamber Educator Guide—https://www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Lunar_Plant_Growth_Chamber.html#.VnLxo_krJhE
- Advanced Astroculture—http://www.nasa.gov/mission_pages/station/research/experiments/185.html
- NASA Facts: Space Launch System—https://www.nasa.gov/pdf/664158main_sls_fs_master.pdf
- Earth’s Moon Overview—http://solarsystem.nasa.gov/planets/profile.cfm?Object=Moon

Strategies and Tips

Before the first student session, several setup procedures need to be completed. During each step of the challenge, the student teams will need to have

1. Access to computers to complete their research
2. Construction materials to build their prototypes
3. Testing areas to collect data describing their designs

Room Setup

The setup of the instructional space (classroom, library, or cafeteria) is almost as important as the challenge itself. A good setup will allow student teams to work together without disrupting each other and to help make sure that the materials needed to complete the EDC are close at hand.

Teams will need plenty of room, especially when building and testing their designs. It may be helpful to consolidate building materials and tools at a table placed either centrally or off to one side of the room so that team areas do not get cluttered during planning steps.

Students should have access to the Internet so that they can conduct their research and investigate questions. There also needs to be a designated testing area where student teams can test and collect data about their prototypes. Make sure to consider safety when selecting a testing area, especially for tests that involve dropping or throwing things.

Differentiated instruction are strategies educators use when responding to varying degrees of student needs and readiness in the classroom. To do this, educators differentiate by modifying the content (what is being taught), the process (how it is taught), and the product (how students demonstrate their learning).

Team Building

Begin by dividing students into teams of no more than four to give all students an opportunity to contribute. By working as a member of a team, students develop skills such as trust, cooperation, and decision making. Working as a team member, however, can be challenging for some students. The following exercises are recommended to help teams begin to work together effectively.

Figure 8.—The Apollo 11 patch with an Eagle landing on the Moon (foreground) and a view of the Earth (background. (NASA)

Establish a team name.—Many NASA teams are named based on the work they do.

Design a mission patch.—Teams that work on NASA missions and spacecraft are unified under a mission patch designed with symbols and artwork to identify the group's mission.

Create a vision statement.—This is a short inspirational sentence or phrase that describes the core goal of the team's work. NASA's current Vision statement is "*To reach for new heights and reveal the unknown so that what we do and learn will benefit all humankind.*"

As students begin to work together, their individual strengths will become apparent. Students can volunteer or be assigned tasks or responsibilities that are vital to completing the challenge. Team jobs can also be rotated throughout the team members to give all students an opportunity to improve their team skills. The following list includes examples of jobs that student teams will need to complete. Feel free to come up with others and remember that all team members should serve as builders and engineers for the team.

Design engineer.—Sketches, outlines, patterns, or plans the ideas the team generates

Technical engineer.—Assembles, maintains, repairs, and modifies the structural components of the design

Operations engineer.—Sets up and operates the glider to complete a test

Technical writer/videographer.—Records and organizes information, data, and prepares documentation, via pictures and/or video to be reported and published

Vocabulary

It is not enough to only build a design to solve the challenge. Students will also need to clearly and accurately communicate their questions and their solutions using STEM vocabulary. Educators can determine the best approach for use of the vocabulary with students. For this challenge, the most relevant words are as follows:

Atmosphere.—Gaseous mass or envelope surrounding a celestial body especially that which surrounds the Earth

Constraints.—The limits placed on the design due to available resources and environment

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

Ecosystem.—An ecological community with its physical environment (living organism)

Growth chamber.—An enclosed space that encourages something to grow

Iteration.—One cycle of a repetitive process

Lunar.—Of, involving, caused by, or affecting the Moon

Lunar atmosphere.—The infinitesimal (compared to Earth's atmosphere) volume of gases surrounding the Moon's surface, consisting of gases including sodium and potassium not commonly found in the Earth's atmosphere

Model.—A small object, usually built to scale, that represents another larger object

Orbit.—The path of a celestial body or artificial satellite as it revolves around another object

Prediction.—The act of attempting to tell beforehand what will happen

Prototype.—An original type, form, or instance that is a model on which later stages are based

Vacuum.—The nearly total absence of gas molecules

Volume.—The quantity of three-dimensional space enclosed by some closed boundary, for example, the space that a substance (solid, liquid, gas, or plasma) or shape occupies or contains

Not all students may be familiar with the vocabulary terms. Educators will need to determine which words require additional explanation and design instructional activities and lead student discussions to demonstrate student understanding of the scientific concepts found within the challenge. Some common instructional activities for building vocabulary include

- Flip books
- Charts
- Manipulatives
- Word charades
- Word drawings
- Restate definitions in own words
- Think-pair-share/elbow reading
- Concept maps
- Classify terms
- Create analogies
- Graphic organizers
- Word sort

Instructional Procedures

The Engineering Design Challenge

The following pages will help guide your students through the EDC. Note that both the educator pages and the student journal section are organized to align with the each EDP step. For example, if you are in Step 4 of the EDP in the educator pages, there will be a corresponding section for Step 4 of the EDP in the student journal.

Background

Future astronaut crews will need to learn how to grow safe, edible, and nutritious plants while living and working in space during long-duration missions. The lunar environment is so extreme that astronauts or plants are not able to live on the lunar surface without a protective habitat. Because of the extreme environment, the lunar habitat must provide the plants with light, water, and atmosphere. All the essential supplies and materials needed to survive on the Moon will be stowed on a rocket, shipped to the Moon, and deployed on the surface. There is a limited amount of space available on the rocket for the large amount of needed lunar cargo. The mass and the volume of the stowed cargo must be closely monitored for fuel efficiency and the limited storage on the rocket.

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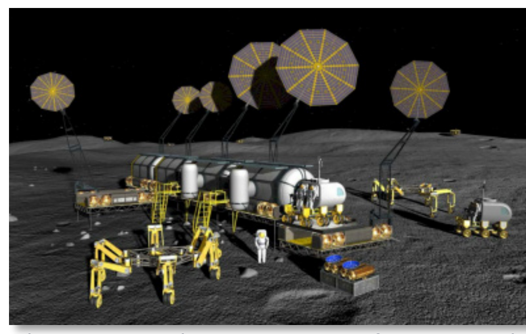


Figure 9.—Artist's concept of a potential lunar outpost (NASA)

Criteria and Constraints

The plant growth chamber must meet the following criteria and constraints:

1. On the rocket, the plant growth chamber model must **not exceed** a mass of 50 grams and a stowed volume of 1000 cm^3.
2. The deployed plant growth chamber can be any shape, however, the volume cannot exceed 1,000,000 cm^3.
3. The deployed plant growth chamber may or may not be connected to the lunar habitat, but it must have a way for the astronauts to have access to the chamber.
4. The model plant growth chamber must use a system of expansion from its stowed shipment package on the rocket to its final deployed structure on the Moon.

Step 1: Identify the Need or Problem

During this step, students will identify what the engineering problem is and begin to think about how it can be solved.

Preactivity Setup

Discuss the rubric with students to provide a clear understanding of the end product and discuss relevant scientific concepts with students, if needed.

Guiding Questions

Use the following guiding questions as discussion prompts to focus student understanding

- How can our team design a _____ that will _____?
- What needs to be solved or improved?
- What are we trying to accomplish?

Instructional Procedure

1. Review the engineering design process with the students.
2. Show the NASA Beginning Engineering Science and Technology (BEST) video titled "Repeatability" found at https://www.youtube.com/watch?v=-2Az1KDn-YM.
3. Ask students to identify the specific criteria and constraints of the design challenge.
4. Have students fill out Step 1 in the Student Journal.

Suggestions for Differentiation

Below are strategies that can be used based on student readiness.

Support:

- Allow students extra time to discuss the challenge itself, the problem that needs to be solved, and how the problem could be solved.
- Introduce criteria and constraints one at a time. Allow student designs to meet one challenge requirement successfully before introducing additional ones.

Complexity:

- Require students to write a letter or an email to a friend as if they were explaining their first job as a newly hired NASA engineer.

Step 2: Research the Need or Problem

Students can use resources from the Internet, the library, or discussions with experts to examine how this problem or similar problems are currently being solved by NASA. For more information, students can view

- LPX First Flight of Lunar Plant Growth—
  www.nasa.gov/centers/ames/cct/office/cif/2013/lunar_plant.html
- Growing the Future: Plants in Space—
  www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Growing_the_Future_Plants_in_Space.html
- How Does the Garden Grow?—
  www.nasa.gov/vision/earth/livingthings/gardengrow.html

Guiding Questions

The following guiding questions may be used as discussion prompts to focus student understanding.

- Where can you find more information about the topic?
- What questions would you ask an expert or an engineer who is currently working on this problem?
- Who in our society will benefit from solving this problem?

Instructional Procedure

1. Help students answer any questions they have about the challenge. Use the Internet or a school library to research answers.
2. Write down any unanswered questions and save them to ask the NASA subject matter expert (SME) during live connections.
3. Use the Know, Learn, Evidence, Wonder, (KLEW) chart to help students think about what they are learning.
4. Have team members fill out Step 2 in the Student Journal.

Suggestions for Differentiation

Below are strategies that can be used based on student readiness.

Support:

- Provide a list of reputable Web resources that students can use
- Arrange a visit to a library
- Pair up students to complete their research together

Complexity:

- Have students provide a properly formatted citation for one or more resources.

Using a KLEW Chart

Educator Directions

The Know, Learn, Evidence, Wonder (KLEW) chart can be used as a starting point for the science investigation. As students complete their research, they can enter their information into each of the chart columns. Students will do the following for each column:

Know: Share prior knowledge and experiences related to the EDP. It is important to enter the information into this column accurately so that facts are written down and not scientific misconceptions students may have. Address any misconceptions and clarify them immediately.

Learn: Record information found during investigations in this column. This information can be found in videos, online articles, and other sources.

Evidence: Record where they got their information and the sources they used to answer their questions.

Wonder: Record new questions they are wondering about as they complete their research.

Remember to let students be flexible with their answers and ideas. Questions can be modified at your discretion.

Know	Learn	Evidence	Wonder
What do I know about plants and plant growth chambers?	**What did I learn about plants and plant growth chambers based on my research?**	**What evidence do I have that supports what I learned about plants and plant growth chambers?**	**What am I still wondering about plants and plant growth chambers?**
Students should complete this column with correct information.	Students should complete this column using supporting information from articles, background information research, direct observation, and SME connections	Students should complete this column with sources of information such as websites or names of experts to contact.	Students should complete this column as they move through the process to document their questions.

Step 3: Develop Possible Solutions

Students draw on their mathematic and scientific knowledge to brainstorm all the possible ways that they might solve the problem. They should choose the most promising options, and refine their solution by quickly sketching their ideas in the space provide in Step 3 of the Student Journal. Labels and arrows should be included to identify all the parts of your sketch.

Guiding Questions

The following guiding questions can be used as discussion prompts to focus student understanding.

- What are all the different ways your team can imagine to solve this?
- What do we need to add to the design?
- What could go wrong if we add to the design?
- Is the team addressing all the criteria and constraints?

Instructional Procedure

1. Ask each team member to brainstorm and make sketches representing their ideas for a solution. Students need to clearly label and identify each part of their drawing.
2. Each team member should make sure that designs meet all constraints and criteria.
3. Have students sketch their ideas on Step 3 in the Student Journal. You could modify this step and show students the building materials to help visualize their sketch prior to beginning the drawing.

Suggestions for Differentiation

Below are strategies that can be used based on student readiness.

Support:

- Encourage students to create a series of storyboards rather than a single complete drawing

Additional Complexity:

- Require students to specify measurements (i.e., the hatch will be 1.25 by 2 cm)

Step 4: Select the Best Possible Solution(s)

During Step 4, student teams should share their ideas and answer each other's questions. Student teams should discuss and record some strengths and weaknesses from each design and determine which solution best meets the original need or solves the original problem. This may include features from more than one design.

Guiding Questions

The following guiding questions may be used as discussion prompts to focus student understanding.

- What is one strength of each student's individual design?
- Are the strengths in each design related to the criteria and constraints of the challenge?
- Are elements from each team member's design represented in the final design?

Instructional Procedure

1. Ask each team member to discuss their ideas and drawings with the rest of the team.
2. Have students record the strengths of each of the designs.
3. Have students fill out Step 4 in the Student Journal.

Step 4: Select the Best Possible Solution(s)

Collaborate with your team to analyze each team member's final drawing using the table below. Based on the team discussions, determine which parts of each design will be used to solve the problem and which features will be included in the final team drawing.

Design number Designer name	Does this design meet all problem criteria and constraints?	What are the strongest elements of this design?	What needs to be improved?
1			
2			
3			
4			

Suggestions for Differentiation

Below are strategies that can be used based on student readiness.

Support:

- Encourage students to create a series of storyboards rather than one complete drawing
- Have students pick one aspect or characteristic from each team member's drawing to discuss in the group

Complexity:

- Require students to draw one or more parts of the design to scale

Step 5: Construct a Prototype

Student teams should construct a prototype (model) of the selected best solution. Educators should help identify and acquire appropriate materials and tools to build the model.

Preactivity Setup

To mirror what engineers do on a daily basis, educators can utilize the budget sheet as an optional activity to add depth to the challenge. Determine a unit cost for each of the materials available and decide the maximum budget each team has to design their prototype. This value can be raised (budget increase) or lowered (budget cut) to adjust the level of challenge difficulty. Teams itemize their budget using the Budget Planning worksheet.

Guiding Questions

The following guiding questions may be used as discussion prompts to focus student understanding.

- What resources does your team need to gather?
- What is the plan?
- Who is doing what?

Instructional Procedure

1. Ask each team to identify the design that appears to solve the problem.
2. A final diagram of the design should be drawn precisely and labeled with a key.
3. Have each team determine what materials they will need to build their design and assign responsibilities to team members for prototype completion.
4. Be sure to approve the final drawings before building begins.
5. After teams receive their materials to build their prototype, have them complete a budget sheet showing their building material costs.
6. Have teams construct their prototypes using their drawings.
7. Have teams fill out Step 5 in the Student Journal.

Suggestions for Differentiation

Below are strategies that can be used based on student readiness.

Supports:

- Give students extra time to use various tactile materials to build the model

Complexity:

- Limit materials (i.e., only 1 meter of duct tape)

Materials

The following is a suggested list of materials needed to complete this challenge. The quantity will depend on the number of students participating. Alternatives can be used if necessary.

- Digital scale or balance (1)
- Measuring tape (1)
- Rulers
- Grid paper
- General building supplies could include

aluminum foil
balloons
binder clips
bubble wrap
buttons or beads
cardboard or cardstock
clothespins
cloth
coffee filters
cotton balls
craft sticks or tongue depressors
empty paper towel or toilet paper tubes
glue sticks
mini foil pie plates
modeling clay
paper bags
paper clips
pennies
plastic eggs
plastic wrap
rubber bands
scissors
skewers or stirrers
staplers and staples
straws
string
tape (masking, electrical, transparent, duct)

Budget Planning Worksheet

Student teams are given a budget sheet like this in the Student Journal:

The budget planning worksheet is included as a differentiation strategy that can be used with students. Educators have the option of including this aspect into the challenge. While not listed as a constraint, students can benefit by gaining an understanding of how today's engineers and scientists work within budget constraints.

Suggestions for Differentiation

Below are strategies that can be used based on student readiness.

Support:

- Use one cost (i.e., every material is $0.25)

Complexity:

- Have students use the Internet to determine realistic costs for the materials they are using
- Item costs can be raised (budget increase) or lowered (budget cut)

Budget Planning Worksheet

Team Name:________________________

Directions: As a team, complete the cost sheet below. Be sure to include all of the materials, quantity, unit cost (determined by your educator), and the total cost to complete your design. Try to keep the cost of your design low while still producing a quality project.

Line item number	Material	Unit cost	Quantity	Item total
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Total cost ____________

Safety

Safety is a special concern for STEM-based courses and activities. School administrators, teachers, and educators are responsible for providing a learning environment that is safe, up to date, and supportive. Educators should inspect and maintain equipment and tools regularly to ensure they are in proper working condition. Educators should also provide safety instructions to students and supervise them while they are working to ensure that safety procedures are being followed.

Students should

1. Make safety a priority during all activities.
2. Wear safety goggles when conducting the challenge.
3. Use tools and equipment in a safe manner.
4. Demonstrate respect and courtesy for other team members.

Educators should

1. Approve all drawings before students start building their model to ensure safety.
2. Look for potential hazardous combinations of flimsy materials and structures.
3. Be sure resources available to student teams are clean, dry and do not have sharp edges.
4. Make sure all materials are not damaged or in disrepair.
5. Prohibit students from bringing in or using additional materials without prior approval.

Step 6: Test and Evaluate the Solution(s)

Student teams should test their prototypes to determine how effectively they addressed the need or problem and collect data to serve as evidence of their success or need for improvement.

Guiding Questions

The following guiding questions may be used as discussion prompts to focus student understanding.

- Did the team collect enough data to analyze the design?
- How did the prototype perform when tested?
- Did the design meet or exceed the criteria and constraints?

Instructional Procedure

1. Visit each team and test their designs to ensure they meet all challenge criteria and constraints.
2. Have teams fill out Step 6 in the Student Journal.

Suggestions for Differentiation

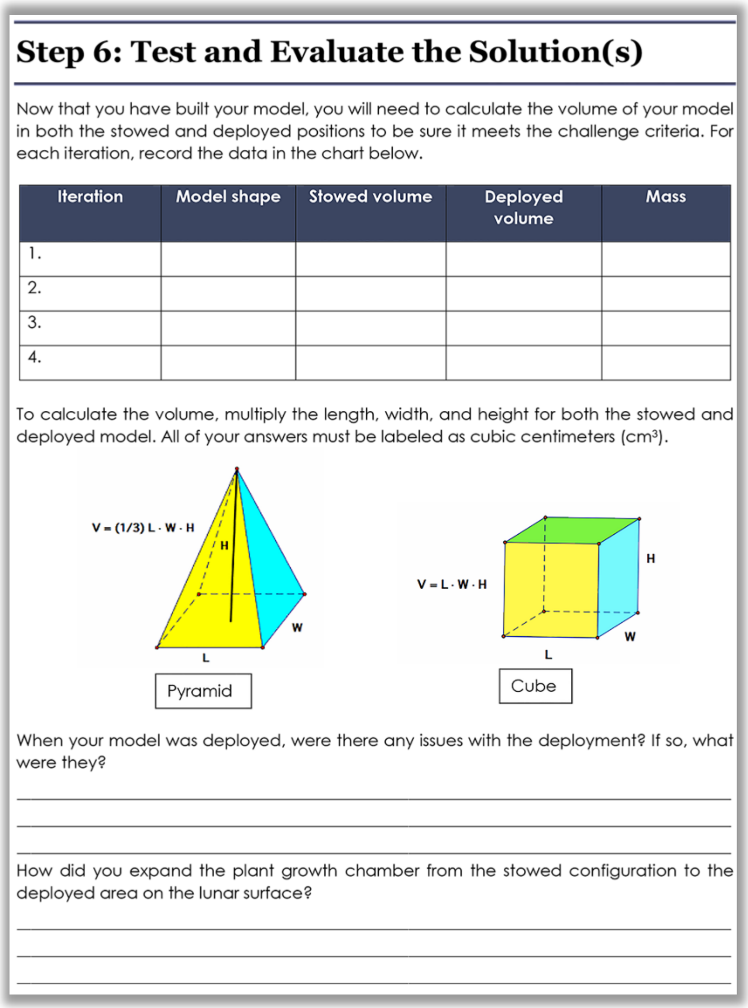
Below are strategies that can be used based on student readiness.

Support:

- Encourage students to test only one criteria or constraint at a time rather than all of them at once.

Complexity:

- Create a scatter plot of test results.



Step 6: Test and Evaluate the Solution(s)

Now that you have built your model, you will need to calculate the volume of your model in both the stowed and deployed positions to be sure it meets the challenge criteria. For each iteration, record the data in the chart below.

Iteration	Model shape	Stowed volume	Deployed volume	Mass
1.				
2.				
3.				
4.				

To calculate the volume, multiply the length, width, and height for both the stowed and deployed model. All of your answers must be labeled as cubic centimeters (cm³).

When your model was deployed, were there any issues with the deployment? If so, what were they?

___

___

___

How did you expand the plant growth chamber from the stowed configuration to the deployed area on the lunar surface?

___

___

___

Step 7: Communicate the Solution(s)

During Step 7, student teams should record and share what they learned about their design based on their tests. Teams will make a presentation to the class that includes how the solution best solved the need or problem and any improvements that could be made. Students may enlist students from other teams to review the solution and help identify changes.

Guiding Questions

The following guiding questions may be used as discussion prompts to focus student understanding.

- What did or did not work in the latest iteration of the design? Why or why not?
- What are the pros and cons of this solution?
- Did each team show they used all steps of the engineering design process?

Instructional Procedure

1. Ask team members to document and report the results of their designs.
2. Have students identify what changes were made with each iteration of the design, and what the team believed caused the design to succeed or fail.
3. Students should complete the Student Reflection sheet in the Student Journal to help them think about how they completed each step of the engineering design process.
4. Students should use the Team Progress Chart to document progress as they work on their solutions.
5. Teams should use the Student Presentation Organizer to guide them through the creation of the team video.

Suggestions for Differentiation

Below are strategies that can be used based on student readiness.

Supports:

- Provide a few basic yes/no questions for students to answer to determine whether their design was successful or not.

Complexity:

- Have students conduct poster presentations and describe their results to other teams.

Step 8: Redesign

During Step 8, student teams should consider modifying their solution based on the information gathered during tests and presentations. Students should revisit the original need or problem to ensure their modifications still meet the necessary criteria and constraints. Teams should go back to the engineering design process (EDP) and decide which step they need to start for their redesign.

Guiding Questions

The following guiding questions may be used as discussion prompts to focus student understanding.

- What design problems did the team identify during testing?
- What did the team do to improve the next iteration of this design?
- What did and did not work?

Instructional Procedure

1. Ask teams to identify the causes of any problems that were observed during testing and to consider possible modifications to solve these problems.
2. Have teams check their redesigned prototype to make sure it still meets all the criteria.
3. Have teams fill out Step 8 in the Student Journal.
4. From here on, the cycle will repeat with redefined problems and redesigned solutions as often as time and resources allow.
5. Depending on the amount of redesign students put into each iteration, some steps may only need a quick revisit to be sure students are on track while some steps will need to be completely redone. **In those cases, additional copies of cycle step pages should be made and added into the Student Journal.**

Submit Final Design

For the final design, use documentation from Step 7 in the Student Journal, the Student Presentation Organizer, and the Team Progress Chart to create a video of the design development and final design solution.

Challenge Rubric

Engineering Design Process	Exemplary = 3	Proficient = 2	Novice = 1	Not Included = 0
Step 1: We can identify the challenge and the criteria.	Challenge restated and all criteria and constraints described.	Challenge restated with only the challenge criteria.	Challenge story only was stated.	Did not include a description of the challenge or the criteria.
Step 2: We can discuss the results of our research and the connections with a NASA subject matter expert (SME).	Three or more facts relating to the challenge were discussed.	Two facts relating to challenge were discussed.	One fact relating to challenge was discussed.	No facts related to the challenge was discussed.
Step 3: Each of our team members constructed an original design that demonstrated the challenge criteria.	All criteria and constraints were represented (sketches and photos) in each team member's design.	Two criteria were represented (sketches and photos) in each team member's design.	One criteria was represented (sketches and photos) in each team member's design.	No criteria was represented.
Step 4: Our final team design represented elements from each team members original design	The team design includes the best from each member's design to represent the challenge and the criteria.	The team design includes ideas from two team members' design to represent the challenge and the criteria.	The team design includes ideas from one team member's design to represent the challenge and the criteria.	The team was not able to provide a design to meet the challenge and the criteria.
Step 5: Our team constructed the model to represent the challenge criteria and constraints.	A model was completed that met all the criteria and the constraints of the challenge.	A model was completed that met only two of the criteria and constraints of the challenge.	A model was completed that met only one of the criteria and constraints of the challenge.	A model was completed that did not meet the criteria or the constraints of the challenge.
Step 6: Our team collected and recorded data to test and evaluate solutions of our model.	Data was collected by testing to represent all the criteria and constraints.	Data was collected by testing to represent only two criteria.	Data was collected by testing to represent only one criteria.	No data was collected or testing completed.
Step 7: Our team is able to explain a difficult issue of our design and how we solved it.	Difficult issues were explained and their solutions described.	Difficult issues were explained with no solutions offered.	Difficult issue was unclear and no solution presented.	Did not have a difficult issue discussion included.
Step 8: Our team made improvements after testing the model.	All improvements to the model were described.	Two improvements were described.	One improvement to the model was described.	No improvements to the model was described.
Our team followed the video production process.	All the video requirements and procedures were met.	Not all of the video requirements and procedures were met.	One of the video requirements and procedures were met.	The video requirements and procedures were not met.

Team Name:______________________________ **Final Team Score:**____________________