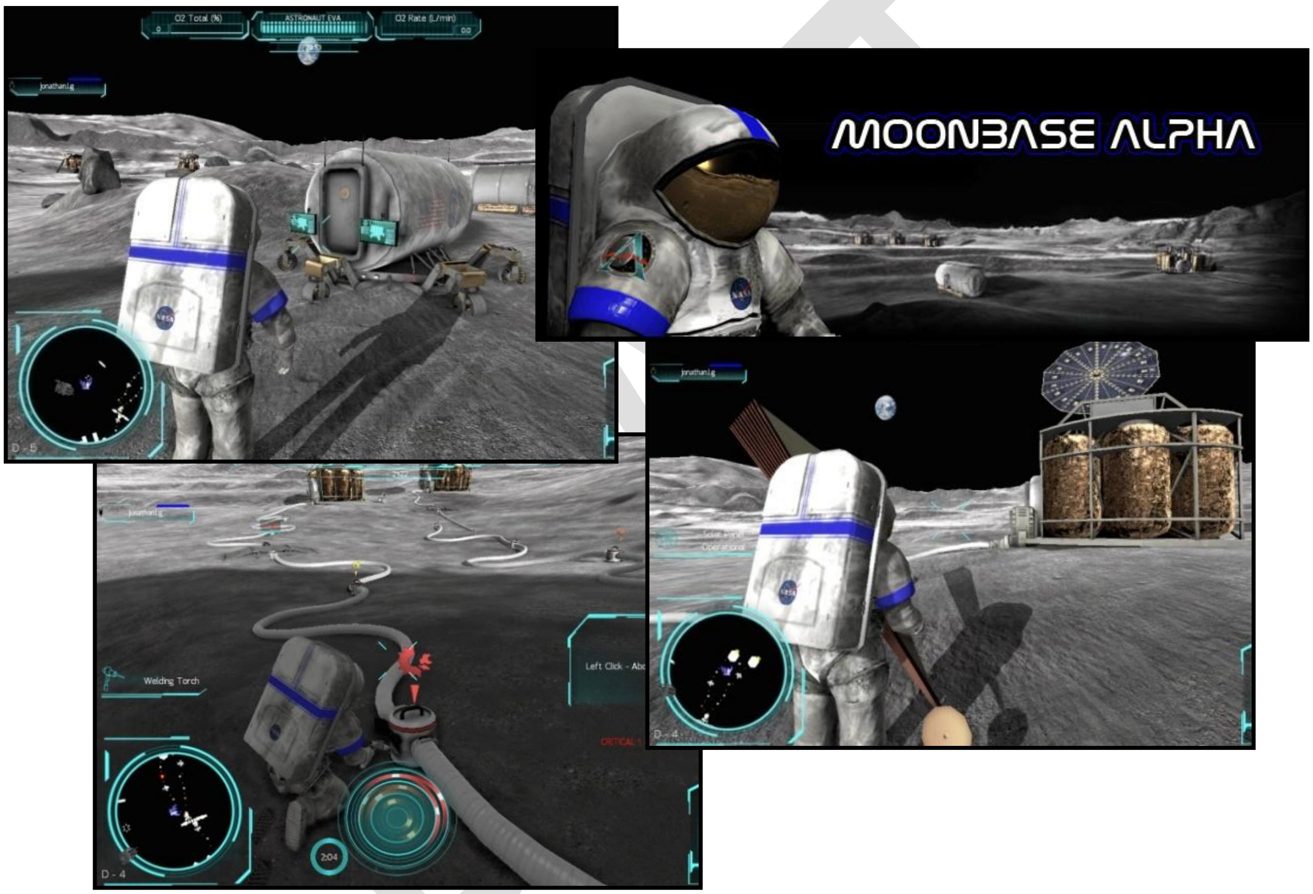
National Aeronautics and Space Administration

NASA *Moonbase Alpha*

Educator Guide



Educational Product	
Educators and Students	**Grades 6 - 9**

www.nasa.gov

DRAFT version: Not yet approved as official NASA educational content.

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LESSON OVERVIEW

Grade Levels:

6 – 9

Subjects:

Physical Science and Earth Science

Lesson Duration:

Four 90-minute class meetings

This lesson was designed based on the 5E instructional model[1] (Engage, Explore, Explain, Extend, Evaluate) and it combines aspects of traditional formal education with game-based learning to teach science, technology, and engineering concepts to students.

Moonbase Alpha is an online game, developed through a partnership between the NASA Learning Technologies Program (LTP) and commercial game developers, which serves as a proof-of-concept to demonstrate that NASA content – lunar architecture in this case – and a cutting-edge game engine can be combined to produce a fun game that inspires interest in STEM education. In *Moonbase Alpha*, commercial-quality gaming technology is combined with accurate physics rendering and real NASA technology to provide a virtual world that can be used to deepen students' understanding of key concepts and improve their teamwork skills. In the game scenario, a meteorite strikes a lunar outpost on the Moon, disabling critical systems that supply oxygen to the astronauts' living quarters. Teams of students will be challenged to repair the damaged systems in order to restore oxygen production capability to the lunar outpost.

During the ENGAGE section of the unit, students will participate in a class discussion about lunar exploration, followed by an introduction to *Moonbase Alpha* and a brief demonstration of the game by the teacher. In the EXPLORE section, students will have the opportunity to get acquainted with the game using its free-play mode. Students will learn about the Moon, energy, gravity, life support systems, and the Engineering Design Process through class discussions and by completing independent research. In the EXPLAIN section, students will discuss their research findings within topic groups and present their answers to the class. In the EXTEND section, students will be asked to consider how the concepts they have learned can be applied to the challenge presented in *Moonbase Alpha*. Students will work in teams to develop strategies for restoring oxygen to the lunar settlement in preparation for playing the game in competitive (timed) mode. After completing the challenge in *Moonbase Alpha's* competitive mode, students EXTEND their thinking as they discuss and record what they have learned and modify

[1] Appendix A contains the full web addresses corresponding to all hyperlinks in this educator guide.

their strategies for approaching the challenge a second time. In the EVALUATE section of the lesson, students discuss what they have learned about science, engineering, and teamwork within their groups and with the class. The Engineering Design Process is integrated throughout the unit, providing a uniting theme through all of the lessons, and it is reinforced as the students work together to develop and implement a strategy for successfully completing the mission in *Moonbase Alpha*.

Each section of this lesson includes suggested time allotments which were developed based on 90 minute class periods; however, time allotments can be adjusted to fit the needs of various class schedules.

Essential Questions

- What is solar energy and how can it be used on the Moon?
- Is gravity different on Earth than on the Moon and are there different gravitational forces for different objects? Why or why not?
- What types of energy are present on the Moon?
- How can the Engineering Design Process be used to solve real-world problems?

Instructional Objectives

Students will:

- Learn about lunar exploration and why it is important for the future of space exploration;
- Learn about gravity, how it impacts motion on the Moon, and how it is different on the lunar surface than it is on Earth;
- Learn about energy sources, energy transformations, and how energy relates to supplying oxygen to a lunar settlement;
- Use the Engineering Design Process to repair damaged systems that produce oxygen for the living quarters for astronauts on a lunar settlement in the game *Moonbase Alpha*;
- Investigate multiple strategies to complete the challenge;
- Use multimedia resources, such as interactive software with graphical interfaces, to demonstrate their proficiency in the use of technology.

STANDARDS ADDRESSED

National Science Education Standards (NSES)

Science as Inquiry

Abilities needed to do scientific inquiry

Understanding about scientific inquiry

Physical Science

Transfer of energy

Earth and Space Science

Structure of the Earth system

Earth in the solar system

Science and Technology

Understandings about science and technology

Science in Personal and Social Perspectives

Populations, resources, and environments

Natural hazards

Risks and benefits

Science and technology in society

History and Nature of Science

Science as a human endeavor

Nature of science

History of science

International Society for Technology in Education (ISTE) National Educational Technology Standards (NETS)

Creativity and Innovation

Students demonstrate creative thinking, construct knowledge, and develop innovative products and processes using technology. Students:

c. use models and simulations to explore complex systems and issues.

Communication and Collaboration

Students use digital media and environments to communicate and work collaboratively, including at a distance, to support individual learning and contribute to the learning of others. Students:

d. contribute to project teams to produce original works or solve problems.

Research and Information Fluency

Students apply digital tools to gather, evaluate, and use information. Students:

a. plan strategies to guide inquiry.

Critical Thinking, Problem Solving, and Decision Making

Students use critical thinking skills to plan and conduct research, manage projects, solve problems, and make informed decisions using appropriate digital tools and resources. Students:

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.

Digital Citizenship

Students understand human, cultural, and societal issues related to technology and practice legal and ethical behavior. Students:

b. exhibit a positive attitude toward using technology that supports collaboration, learning, and productivity.

Commonwealth of Virginia Standards[2]

6th Grade Science

Standard 6.2

Key concepts:

a) Potential and kinetic energy

b) The role of the Sun in the formation of most energy sources on Earth

d) Renewable energy sources

e) Energy transformation

At the end of the lesson the student should be able to:

- comprehend and apply basic terminology related to energy sources and transformations.
- compare and contrast potential and kinetic energy through common examples found in the natural environment.
- compare and contrast renewable and nonrenewable energy sources.
- analyze the advantages and disadvantages of using various energy sources.

Standard 6.8

Key concepts:

a) The Sun, Moon, Earth, other planets and their moons, meteors, asteroids, and comments; The solar system consists of the Sun, Moon, Earth, outer planets and their moons, meteors, asteroids, and comments. Each body has its own characteristics and features.

c) The role of gravity; Gravity is a force that keeps the planets in motion around the Sun. Gravity acts everywhere in the universe.

d) Revolution and rotation of the Moon

i) The history and technology of space exploration

[2] This educator guide was aligned with Virginia standards because it was developed at the NASA Langley Research Center in Hampton, VA; however, the concepts addressed in the guide can be aligned to other state standards as needed.

At the end of the lesson the student should be able to:

- discuss the difference between the force of gravity on Earth and the force of gravity on the Moon.

Physical Science

Standard PS.6

Key concepts:

a) Potential and kinetic energy

b) Mechanical, chemical, and electrical energy

c) Heat, light, and sound

At the end of the lesson the student should be able to:

- differentiate between potential and kinetic energy.
- use diagrams or concrete examples to compare relative amounts of potential and kinetic energy.
- identify and give examples of common forms of energy.

Earth Science

Standard ES.4

Key concept:

d) The history and contributions of the space program

Essential Knowledge:

- Apollo 11 was the first manned landing on the Moon.

Standard ES.7

Key concept:

b) Advantages and disadvantages of various energy sources

Essential Knowledge:

- Nonrenewable resources are renewed very slowly or not at all.

<u>Standard ES.12</u>

Key concept:

c) Comparison of Earth's atmosphere to that of other planets

Essential Knowledge:

- The Moon has virtually no atmosphere and is considered to be surrounded by a vacuum.

Computer/Technology

Basic Operations & Concepts

<u>C/T6-8.1</u>

The student will demonstrate knowledge of the nature and operation of technology systems:

- Describe how technology impacts learning.

<u>C/T6-8.2</u>

The student will demonstrate proficiency in the use of technology:

- Use self-help features such as online tutorials and manuals to learn to use hardware and software.

Social & Ethical Issues

<u>C/T6-8.3</u>

The student will demonstrate knowledge of ethical, cultural, and societal issues related to technology:

- Explore career opportunities in technology related careers.

<u>C/T6-8.4</u>

The student will practice responsible use of technology systems, information, and software:

- Demonstrate compliance with the school division's Acceptable Use Policy and other legal guidelines.

C/T6-8.5

The student will demonstrate knowledge of technologies that support collaboration, personal pursuits, and productivity:

- Work collaboratively and/or independently when using technology.
- Explore the potential of the Internet as a means of personal learning and the respectful exchange of ideas and products.

Technology Research Tools

C/T6-8.6

The student will use technology to locate, evaluate, and collect information from a variety of sources.

- Use databases and spreadsheets to evaluate information.
- Use technology resources such as calculators and data collection probes for gathering information.
- Use the Internet and other electronic resources to locate information in real time.

Problem-solving & Decision-making Tools

C/T6-8.8

The student will use technology resources for solving problems and making informed decisions.

- Employ technology in the development of strategies for solving problems.
- Use a variety of technologies to identify and provide possible solutions to real-world problems.
- Use content-specific tools, software, and simulations such as environmental probes, graphic calculators, exploratory environments, and web tools.
- Participate in collaborative problem-solving activities.
- Select and use appropriate tools and technology resources to accomplish a variety of tasks.

Massachusetts Science and Technology/Engineering Curriculum Framework[3]

Technology/Engineering

1.2: Identify and explain appropriate measuring tools, hand tools, and power tools used to hold, lift, carry, fasten, and separate, and explain their safe and proper use.

Engineering Design

2.1: Identify and explain the steps of the Engineering Design Process, i.e., identify the need or problem, research the problem, develop possible solutions, select the best possible solution(s), construct a prototype, test and evaluate, communicate the solution(s), and redesign.

[3] Currently (as of March 2011), the Virginia standards do not include engineering; Massachusetts standards were used to demonstrate the applicability of this educator guide to engineering-related educational standards.

TEACHER PREPARATION

Computer Lab Setup

Review system requirements with your school's information technology (IT) director[4]. It is recommended that ample time is provided prior to teaching the unit for the IT director to ensure computer capabilities and verify regulations related to accessing the game on the Steam server through the school's firewall. Note that routine access to the necessary servers for this unit is not common and will likely require action on the part of the school's IT department. For technical support, contact: MBASupport@virtualheroes.com.

Minimum System Requirements:

- Win XP SP3
- 2.0+ GHZ Single Core Processor
- 2GB of System RAM
- NVIDIA 7000-series or ATI Radeon X1900 Video Card
- 2.0GB of Free Hard Drive Space
- DirectX 9.0c

Recommended System Requirements:

- Win XP SP3/Vista/Windows 7
- 2.4+ GHZ Dual Core Processor
- 4GB+ of System RAM
- NVIDIA 9000+ or ATI Radeon 3600+ Video Card
- 5.0GB of Free Hard Drive Space
- DirectX 9.0c for XP/Vista
- DirectX 10.0 for Windows 7

Network Requirements:

Network must be configured to allow the Steam client access to the following ports (may require removal of normal firewall rules):

- 9777 TCP/UDP
- 8766 UDP
- 27016 UDP

Prior to Class Meeting 1:

1. Create a Steam account for each computer.
   a) Go to http://store.steampowered.com/, click on "login" in the top right, and then click "Join Steam".
   b) Create a user name and password and provide an email address for each account. Steam requires a unique email address for each user account in order to verify the user's validity. It is recommended that the instructor create dedicated email accounts with similar names (e.g. myStudent1, myStudent2, etc) using a free email service provider such as Gmail.
   c) Select a challenge question and answer, enter the security code as provided in the image, review and accept the Steam Subscriber Agreement, and click "Create My Account".
   d) Log into the respective email account and click the link to verify the account.

[4]Currently (as of March 2011), *Moonbase Alpha* can only be accessed through the Steam server; however, a stand-alone DVD version is in development which will enable *Moonbase Alpha* to be played without the need to access Steam or create student email accounts.

2. Install Steam on each computer. Go to http://store.steampowered.com/, click on "Install Steam" in the top right, and follow the installation instructions.

3. Configure Steam settings.

    a) Once installed, launch the Steam client and click "settings" from the "Steam" drop down menu at the top left.

    b) On the "Account" tab, check "Do not save account credentials on this computer".

    c) On the "Friends" tab, uncheck "Automatically sign into Friends when I start Steam".

    d) On the "Interface" tab, uncheck "Run Steam when my computer starts".

    e) On the "In-Game" tab, uncheck "Enable Steam Community In-Game".

4. Install *Moonbase Alpha* on each computer.

    a) From the search box in the top right of the Steam client, search for *Moonbase Alpha* and click "Install Game".

    b) It is recommended that the Instructor start the *Moonbase Alpha* game at least two times after initial installation.

<u>On the day of Class Meeting 1:</u>

1. It is recommended that the teacher log into each Steam account, start *Moonbase Alpha*, and create a password protected instance of *Moonbase Alpha* for each group of four students prior to the students entering the computer lab.

    a) Select one machine in each group of four computers from which to create the game. Launch *Moonbase Alpha* and click the "Create" button.

    b) Select "3-4 Player", "Freeplay Mode", "Password protected" and "Play opening cinematic".

    c) Choose a unique server name, select a password and click the "Create" button.

    d) From each of the other 3 computers in the group, launch *Moonbase Alpha* and click the "Join Game" button. Select the unique server name for the group and click the "Join" button.

2. Assign each student to a computer.

3. Students should have headphones to use during game play.

4. To minimize distractions, the monitors should be turned off while the students are not playing the game.

5. When ready to play in freeplay mode, instruct the students to click the “Start” button from the machine that created the game.

Additional notes related to security:

- *Security note*: Students must be observed to ensure that they are not misusing the computers. Students are not to be allowed to have access to Steam account passwords, download or play any games besides *Moonbase Alpha*, or visit internet sites except for research purposes.

- Built-in security features include password protection on the games (so that no one else can log in to the students’ games) and blocking of offensive language in the chat boxes.

Pre-Lesson Assessment

If desired, have students complete the pre-lesson assessment questions (Appendix B). The pre-lesson assessment may be completed a few days in advance in order to gauge the students’ understanding of the concepts to be covered in this lesson.

Opportunities for Teachers

Four areas of interest for teachers are identified throughout the lesson:

(TECHNOLOGY) highlights opportunities to use technology to enhance the lesson.

(MODIFICATION) denotes opportunities to differentiate the lesson.

(RESOURCES) relates this lesson to other educator resources that may supplement or extend the lesson.

(CHECKING FOR UNDERSTANDING) suggests quick, formative assessment opportunities.

5E Inquiry Lesson Development

Outline

Class Meeting 1 (ENGAGE & EXPLORE)

- Discussion of lunar exploration and Apollo history (30 minutes)
- Introduction to *Moonbase Alpha*, science concepts, and Engineering Design Process (40 minutes)
- Conduct research and complete EXPLORE worksheets (20 minutes)

Class Meeting 2 (EXPLAIN & EXTEND)

- Topic team discussions and student presentations about research findings documented in EXPLORE worksheets (60 minutes)
- Application of research topics to *Moonbase Alpha* (5 minutes)
- Introduction to team challenge (5 minutes)
- Team strategy development for solving the challenge presented in *Moonbase Alpha* (recorded in EXTEND logbooks) (20 minutes)

Class Meeting 3 (EXTEND & EVALUATE)

- Finalization of team strategies (5 minutes)
- Round 1 of *Moonbase Alpha* in competitive mode (25 minutes)
- Team discussion of successes, areas for improvement, and revision of strategies (recorded in EXTEND logbooks, 15 minutes)
- Round 2 of *Moonbase Alpha* in competitive mode (25 minutes)
- Discussion of impacts of the revised strategies (recorded in EVALUATE logbooks, 20 minutes)

Class Meeting 4 (EVALUATE)

- Team presentations about experiences with *Moonbase Alpha* (60 minutes)
- Discussion to link *Moonbase Alpha* back to science concepts (10 minutes)
- Post-lesson assessment (optional, 20 minutes)

Class Meeting 1

ENGAGE: 45 minutes

1. Discuss the history of lunar exploration and why NASA is interested in creating and establishing a base on the Moon, and then introduce the students to some of the concepts that will be covered in this lesson. Listed below are several questions that can be used to guide the discussion. Allow **30 minutes** for this discussion.

    - What was the Apollo Program? Apollo was the NASA program that resulted in American astronauts making a total of 11 spaceflights and walking on the Moon. The purpose of the first four flights was to test the equipment that would be used throughout the Apollo Program. Six of the other seven flights landed on the Moon. The first Apollo flight occurred in 1968 and the first Moon landing took place in 1969. The last Moon landing was in 1972. A total of 12 astronauts walked on the Moon where they conducted scientific research. They studied the lunar surface and collected Moon rocks to bring back to Earth.

      (RESOURCES) More information on the Apollo Program can be found in the student section of NASA's website.

    - Why was the Apollo Program created? In 1961, President John F. Kennedy challenged the nation to land astronauts on the Moon by the end of the decade. NASA met that challenge through the Apollo Program, marking the first time human beings left Earth's orbit.

    - When did humans first visit the Moon? The first manned mission to the Moon was Apollo 8. It orbited the Moon on Christmas Eve in 1968 and then returned to Earth. The crew members were Frank Borman, Bill Anders and Jim Lovell. The first Moon landing occurred on July 20, 1969, on the Apollo 11 mission. The crew of Apollo 11 included Neil Armstrong, Michael Collins and Buzz Aldrin. Armstrong and Aldrin walked on the lunar surface while Collins remained in orbit around the Moon. When Neil Armstrong became the first person to walk on the Moon, he said, "That's one small step for (a) man; one giant leap for mankind."

      (TECHNOLOGY) Play the audio link.

    - How did astronauts explore the Moon? On the last three missions, astronauts drove on the Moon with a lunar rover to explore more of the Moon's surface. The lunar rovers were made so they could be folded to fit in a storage area on the Lunar Module, and they were left on the Moon when the astronauts returned to Earth.

- How did astronauts get back to Earth from the Moon? When the astronauts were finished working on the Moon's surface they returned to the Lunar Module, which launched from the Moon's surface and went back into orbit around the Moon. The Lunar Module connected with the Command Module in orbit, and the astronauts moved into the Command Module to return to Earth. The Lunar Module was left behind and inevitably crashed into the Moon after it was no longer under the astronauts' control. The Command Module entered the Earth's atmosphere and landed in the ocean, where a boat was sent to pick up the astronauts.

- Do we currently have a settlement on the Moon? Discuss why or why not. No, there is not a Moon settlement currently.

  (RESOURCES) Read more about space settlement basics on the NASA Ames Research Center website.

- Why might we want to return to the Moon?

  - To prepare for future human and robotic missions to Mars and other destinations
  - To accumulate scientific knowledge and pursue scientific activities addressing fundamental questions about the Earth, the solar system, and the universe
  - To extend our civilization beyond Earth
  - To strengthen existing global partnerships and create new ones
  - To engage, inspire, and educate the public
  - To develop innovative ways to produce "green" energy
  - To develop technologies that benefit society

  (RESOURCES) NASA's Exploration 101 Presentation

The supplemental questions listed below may be used to guide a more detailed discussion.

- What is needed to live and work on the Moon?
- What types of energy are available on the Moon?
- How do solar panels work?

- How does oxygen get transported around a lunar settlement?
- What kind of damage could be caused by a meteorite impact? How would such damage be fixed?

(RESOURCES) More information can be found at the following lunar education websites:

- Moonbase Alpha Exploration Training Lunar Resources (NASA)
- History of the Apollo era (NASA)
- World Book at NASA (Moon) (NASA)
- Lunar Reconnaissance Orbiter Student Activities (NASA)
- Moon activities (Lunar and Planetary Institute)
- Lunar Photo of the Day (Wikispaces)

2. Using the overview description below, describe the game to the students. On your computer (which should be set up for overhead projection and sound) show the cinematic introduction to the game, which explains the challenge. Once the cinematic introduction (approximately **5 minutes**) is completed, conduct a demonstration of the game for about **10 minutes**, until the students have a basic understanding of the essential elements of *Moonbase Alpha* (outlined below).

   (RESOURCES) Refer to the *Moonbase Alpha* Overview for Teachers (Appendix C), the help menu within the *Moonbase Alpha* game (using the F1 key), or the *Moonbase Alpha* website for more information.

   (MODIFICATION) Consider asking the students to read the *Moonbase Alpha* Overview for Students (Appendix D) for homework prior to starting the lesson in order to increase their level of understanding of the challenge, the components of the settlement, and the tools that will be available to them.

   - Overview of the challenge (from NASA's *Moonbase Alpha* website): NASA has once again landed on the lunar surface with the goal of colonization, research, and further exploration. Shortly after the return to the Moon, NASA has established a small outpost on the south pole of the Moon called *Moonbase Alpha*. Utilizing solar energy and regolith processing, the Moonbase has become self-sufficient and plans for further expansion are underway. In *Moonbase Alpha*, you assume the exciting role of an astronaut working to further human exploration and research. Returning from a research expedition, you witness a meteorite impact that cripples the life support capability of the settlement. With precious minutes ticking away, you and your team must repair and replace equipment in order to restore the oxygen production to the settlement. Team coordination along with the proper use and allocation of your available resources (player controlled robots, rovers, repair tools, etc.) are key to your overall success. There are several ways in which you can successfully restore the life support system of the lunar base, but since you are scored on the time spent to complete the task, you have to work effectively as a team, learn from decisions made in previous gaming sessions, and make intelligence decisions in order to be successful.

- Controls
    - Map (“M” key)
    - Help menu (“F1” key)
    - Exit game (Hit “ESC” then choose “Quit” then “Accept”)
- Key components of the settlement
    - Equipment shed
    - Command center
    - Power distributor
    - Solar arrays
    - Cables & couplers
- Item Damage
    - Damage levels
    - Repair vs. replacement
- Tools
    - Types of tools and their uses
    - Welding “shortcut” game
    - Toolboxes

- Rover
    - Driving
    - Loading with equipment
- Robots
    - How and when to use
    - Tradeoffs during creation

EXPLORE: 45 minutes

1. Allow the students to play the game in free play mode for approximately **10 minutes** (see instructions in the "Teacher Preparation" section). After free play and prior to teaching the lesson, instruct students to turn off their monitors.

   (TECHNOLOGY) Project your computer screen and display the help menu (using the F1 key) This serves as a reminder for the students about how to use the in-game controls.

2. Use the questions below to guide a class discussion about the Moon, gravity, energy, and the Engineering Design Process and relate them to *Moonbase Alpha*. Allow **15 minutes** for this discussion.

   - Why do people move slowly on the Moon? The force due to gravity at the lunar surface is only about 1/6 of that on Earth. This means that after jumping or taking a step, an astronaut will go higher on the Moon than he or she would on Earth for a jump or step of the same energy. Also, it takes longer for an astronaut to return to the surface of the Moon because the gravitational force pulling him or her down is not as strong as on Earth.
   - What is the primary source of power on the Moon? Energy from the Sun (solar energy).
   - Discuss the Engineering Design Process and how it can be applied to the challenge presented in *Moonbase Alpha.*

   I. Identify the problem
      - Oxygen production system & power supply are damaged

   II. Research the problem and identify constraints
      - What do we need to know to solve the problem?

- How damaged are the components?
- How important are each of the components?
- How long does it take to repair each component?
- How many people are on the outpost?
- What tools can be used, and which are the most effective?
- How can we move around the outpost efficiently?

III. Brainstorm possible solutions

- Identify all tools available
- Move tools around, place in strategic locations
- Methods of communication

IV. Select the best solution and justify your choice

V. Construct prototype (not covered in this educator guide)

VI. Test and evaluate

VII. Communicate solutions

VIII. Re-design

(RESOURCES) A variation on the Engineering Design Process can be found on NASA's educator resources website.

- What difficulties do the students anticipate encountering during this mission? (*Mention that this aligns with Step 1 in the Engineering Design Process)*.
  - Time constraints
  - Deciding which items are the most important to fix first
  - Figuring out whether to repair or replace damaged items
  - Figuring out what tools are needed to repair items
  - Creating and controlling a robot to fix items in the hazardous areas where astronauts are not allowed to enter
  - Working as a team to complete the challenge

The supplemental questions listed below may be used to guide a more detailed discussion.

- Why is solar energy the best form of energy to use on the Moon?
- How long does it take for the Moon to rotate on its own axis? Around the Earth?
- How much light is available on the Moon for production of solar energy?

3. Divide students into teams of four. Within each four-person team, each student is responsible for researching one of four topics: the Moon, gravity, energy, or lunar life support systems. At your discretion, assign students to topics or allow them to decide within their groups. Each student will be given an EXPLORE worksheet (Appendix D) to complete, which includes questions related to the research topic and a list of websites to use as references. Allow students to conduct research for **20 minutes**.

   (TECHNOLOGY) To facilitate the students' research, provide the students with an electronic copy of the EXPLORE worksheets so that they can use the links to the reference websites.

   (MODIFICATION) To save class time, EXPLORE worksheets can be given to the students to be completed as homework.

   (MODIFICATION) Ask the students to create at least one question, find the answer, and be ready to present to the class.

Class Meeting 2

EXPLAIN: 60 minutes

1. Instruct the students to gather into teams based on their topic areas; for example, all of the students that were tasked with researching the Moon will be grouped together. Instruct students to discuss their research findings within their topic groups and come to a consensus on all of the answers to the questions on the EXPLORE worksheets. Allow the students **15 minutes** to meet in their topic groups to verify that they agree on all answers before presenting to the class.

   (MODIFICATION) If the students created their own questions, teachers could use this time to check these questions and their answers. Instruct each team to select one student-generated question to present to the class (after the answer has been verified by the teacher).

2. Allow **10 minutes** for each topic group to present the answers to the questions on the EXPLORE worksheet (**40 minutes total**). Each student is responsible for discussing at least one question. Each student in the class should be given all four EXPLORE worksheets and should fill in the answers as the topic groups present their findings.

   (MODIFICATION) If the students created their own questions, then one representative from each group should present the group's chosen student-generated question.

3. Depending on the level of discussion among students, teachers may want to take about **5 minutes** to reinforce the basic concepts and answer lingering questions.

EXTEND: 30 minutes

1. Encourage the students to consider what they have learned through their research and how it applies to the scenario in the game. Allow **5 minutes** for this discussion. Mention that this aligns with the Step 2 in the Engineering Design Process (research the problem and identify constraints).

   (CHECKING FOR UNDERSTANDING) Ask students to consider the following:

   - Why do you need this information to complete the challenge presented in *Moonbase Alpha*?
   - How will this information help you make better in-game decisions?

2. To introduce the students to their *Moonbase Alpha* team challenge, tell them that they will be working together to solve problems and, just like a real crew of astronauts, making use of the strengths of their team members. Discuss the importance of teamwork. Allow **5 minutes** for this discussion.

3. Direct students to work in their original 4-person teams to develop an approach to their *Moonbase Alpha* team challenge, using steps 1-4 of the Engineering Design Process (identify the problem, research the problem and identify constraints, brainstorm possible solutions, select the best solution and justify your choice). Students may refer to the *Moonbase Alpha* Overview for Students (Appendix D).

   - Encourage the students to revisit Steps 1 and 2, discussing problems they may encounter in game play and identifying the constraints under which they will be working. Some of the items that the students should consider are listed below:
     - Use of in-game items (help menus, rovers, tool box, replacement parts, robots, etc.)
     - Prioritization and decisions between making repairs vs. replacements
     - Crew resource management – what tools are necessary to complete a job, rover, welding device, which members of the team should be performing what actions and when, etc.
   - To complete Engineering Design Process Steps 3 and 4, the teams should develop a strategy for restoring oxygen to the lunar settlement. Instruct the students to document this strategy in their EXTEND logbooks.
   - Allow **15 minutes** for team discussion and **5 minutes** for students to individually document their team's strategy in their EXTEND logbooks.

   (RESOURCES) The *Moonbase Alpha* Overview for Teachers (Appendix C) contains several tips and strategies that may be useful in guiding the students' discussions.

Class Meeting 3

Prior to the start of this class meeting, it is recommended that the teacher log into each Steam account, start *Moonbase Alpha*, and create a password protected instance of *Moonbase Alpha* for each group of four students prior to the students entering the computer lab, as follows:

a) Select one machine in each group of four computers from which to create the game. Launch *Moonbase Alpha* and click the "Create" button.

b) Select "3-4 Player", "Competitive Mode", "Password protected" (do not select "Play opening cinematic").

c) Choose a unique server name, select a password and click the "Create" button.

d) From each of the other 3 computers in the group, launch *Moonbase Alpha* and click the "Join Game" button. Select the unique server name for the group and click the "Join" button.

e) When ready to play in competitive mode, instruct the students to click the "Start" button from the machine that created the game.

EXTEND (cont'd): 75 minutes

1. Allow students to re-group into their 4-person teams to refresh their memories about the strategies they developed during the previous class meeting. Allow **5 minutes**.

2. Instruct students to enter *Moonbase Alpha* and join the games assigned to their respective teams. These games will be played in competitive mode; therefore, students will only have **25 minutes** to restore oxygen to the lunar habitat. Inform students that this represents the first part of Step 6 (<u>test</u> and evaluate) in the Engineering Design Process, during which the teams will be implementing and testing the strategies that they developed with their teams. Once all students have accessed the game, give them the "go ahead" to proceed in the competitive mode.

3. After the time has expired, instruct students to individually record whether or not they completed the mission in their EXTEND logbooks. On the chalkboard, record which teams completed the mission and also how long it took the teams that were successful. Remind the students that this aligns with the second part of Step 6 in the Engineering Design Process (test and <u>evaluate</u>). Allow **5 minutes**. Ask students to consider the following:

   - What strategy did your team use? Why?

- Were you successful at completing the mission? If so, what made you successful? If not, what were some of the challenges that prevented you from completing the mission?

4. Inform the students that they will be given a second chance to complete the challenge presented in *Moonbase Alpha*. Allow them to break out into their 4-person teams to discuss the observations they recorded on their own and come to a consensus on how they can improve their strategies. Remind the students that they are working on Steps 7 and 8 in the Engineering Design Process (communicate solutions and re-design) since they are identifying the strengths and weaknesses of their initial strategies and working together to refine them. Allow **10 minutes** for this discussion. Ask students to consider the following:

   - If your team succeeded at the mission, how could you increase your efficiency and improve your time?
   - If your team did not succeed at the mission, can you identify a different approach?
   - Encourage the students to discuss both technical and team oriented challenges.

   While the students discuss their strategies, create new a password protected game for each team.

5. Instruct the students to re-enter *Moonbase Alpha* and join the competitive mode games assigned to their respective teams (**25 minutes**). By testing their revised strategies, students are re-visiting the first part of Step 6 of the Engineering Design Process (<u>test</u> and evaluate). The instructor should assign and assist one student per team to create a password protected game for the others to log into.

6. On the chalkboard, record which teams completed the mission and also how long it took the teams that were successful. Briefly discuss how the teams performed, noting any items of particular interest (change in the number of teams that succeeded, improvements in the time it took to complete the challenge, etc.). Allow about **5 minutes**.

EVALUATE: 15 minutes

1. Allow the students to break out into their teams again to discuss how their re-designed strategies changed their experience of restoring oxygen to the lunar settlement. Remind the students that this corresponds to the second part of Step 6 of the Engineering Design Process (test and <u>evaluate</u>). Direct the students to record

the highlights of their discussions in their EVALUATE logbooks. Allow **15 minutes** for this discussion. Ask the students to consider the following:

- What did your team do differently the second time you played?
- If your team did not complete the challenge the first time you played, did you complete it the second time? If your team completed the challenge both times, did your time improve?
- Was your team successful? If so, what made you successful?
- What were some of your pitfalls?
- How did your team assign roles?
- What team member qualities were valuable in making your team work well together?

(MODIFICATION) For homework, instruct the students to continue thinking about how their team worked together and record their thoughts in preparation for a class discussion.

Class Meeting 4

EVALUATE (cont'd): 90 minutes

1. Direct each team to present their findings, including team dynamics, to the class. Ask the students to start by stating whether or not they completed the mission and whether or not their times improved when they played a second time. Allow approximately 10 minutes per team, up to a total of **60 minutes**. Remind students that this aligns with Step 7 in the Engineering Design Process (communicate solutions).

2. To bring closure to the lesson, provide some guiding questions that tie back to science. Allow **10 minutes** for this discussion. Suggested questions include:

   - Brainstorm other occupations that benefit from the Engineering Design Process.
   - Can you think of technologies that would have made your task in *Moonbase Alpha* easier? Have they been invented yet?
   - Are there other dangers or complications that astronauts would face on the moon that were not depicted in *Moonbase Alpha*?

   (CHECKING FOR UNDERSTANDING) Use the following questions to guide the class discussion:

   - How are the topics that the students researched earlier in the unit related to the challenge in *Moonbase Alpha*?
   - Did this knowledge help you to develop or carry out your strategy? How?

3. If desired, distribute the post-lesson assessment questions (Appendix B) to the students. Allow **20 minutes**.

About *Moonbase Alpha*

Moonbase Alpha, released in July 2010, was developed by the Army Game Studio with primary development support from Virtual Heroes, a division of Applied Research Associates, which specializes in interactive instructional design to simultaneously inspire and educate. *Moonbase Alpha* is the demo version of a NASA Massively Multiplayer Online Game (MMOG) called *Astronaut: Moon, Mars, and Beyond*, which is currently under development by a team of commercial game developers (Virtual Heroes, Project Whitecard, and Wisdom Tools). *Moonbase Alpha* was built on Epic Games' Unreal Engine 3 and released on Valve's Steam network. In 2010, *Moonbase Alpha* won the award for Best Government Entry and the Serious Games Showcase and Challenge.

Moonbase Alpha websites:

NASA's *Moonbase Alpha* homepage

Virtual Heroes' *Moonbase Alpha* homepage

NASA Games YouTube Channel

NASA Games on Facebook

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Finally, we would like to thank the users of educator guide for being innovative teachers, engaging students to learn in different ways, and brining NASA content to the classroom.

APPENDIX A: WEB ADDRESSES CORRESPONDING TO EMBEDDED HYPERLINKS

- 5E Instructional Model: http://www.nasa.gov/audience/foreducators/nasaeclips/5eteachingmodels/index.html
- NASA's *Moonbase Alpha* homepage: *http://www.nasa.gov/moonbasealpha*
- Apollo Program information: http://www.nasa.gov/audience/forstudents/5-8/features/what-was-apollo-program-58.html
- Apollo audio link: http://www.hq.nasa.gov/alsj/a11/a11.step.html.
- Space Settlement Basics: http://settlement.arc.nasa.gov/Basics/wwwwh.html
- NASA's Exploration 101 Presentation: http://www.nasa.gov/directorates/esmd/library/exploration_101.html
- Moonbase Alpha Exploration Training Lunar Resources: http://www.nasa.gov/offices/education/programs/national/ltp/games/moonbasealpha/mbalpha-landing-collection1-TrainingResources.html
- History of the Apollo era: http://www.nasa.gov/mission_pages/apollo/
- World Book at NASA (Moon): http://www.nasa.gov/worldbook/moon_worldbook.html
- Lunar Reconnaissance Orbiter Student Activities: http://lunar.gsfc.nasa.gov/forkids.html
- Moon activities: http://www.lpi.usra.edu/education/theMoon/
- Lunar Photo of the Day: http://lpod.wikispaces.com/
- Engineering Design Process: http://www.nasa.gov/audience/foreducators/plantgrowth/reference/Eng_Design_5-12.html
- *Astronaut: Moon, Mars, and Beyond* homepage: *http://www.astronautmmo.com/dmf/*
- Virtual Heroes' *Moonbase Alpha* homepage: http://www.moonbasealphagame.com/
- NASA Games YouTube Channel: http://www.youtube.com/user/nasagames
- NASA Games on Facebook: http://www.facebook.com/NASAgames
- NASA FIRST Program homepage: http://leadership.nasa.gov/nasa_first/home.htm

APPENDIX B: PRE- AND POST-LESSON ASSESSMENT QUESTIONS

(Students & Teachers)

Pre-Lesson Assessment Questions for Students

Name: ______________________________
Date: ______________________________
School: ______________________________
Class/Grade: ______________________________
Teacher: ______________________________

Please answer the following questions.

If the question includes a "level of confidence" indicator, then circle a number based on how sure you are about your answer using the following scale:

1: I didn't know the answer so I made my best guess.
2: I'm not sure about my answer.
3: I think my answer is correct.
4: I'm very sure that my answer is correct.

1. What, if any, previous experiences have you had with game-based learning?

2. Are there any subjects that you would want to have taught using video games?

3. Energy is defined as the ability to ____________.

   Level of confidence: 1 2 3 4

4. Most energy on Earth comes, in one way or another, from _____ ______.

   Level of confidence: 1 2 3 4

5. Describe the difference between potential energy and kinetic energy.

   Level of confidence: 1 2 3 4

6. Several forms of energy are listed below:

- *Chemical*
- *Radiant*
- *Mechanical*
- *Gravitational*
- *Electrical*
- *Motion*
- *Sound*

For each of the following examples, list the correct form of energy and indicate whether it is an example of potential or kinetic energy by writing a "P" or a "K" in the third column:

Examples	**Form of Energy**	**Potential [P] or Kinetic [K]**	**Level of Confidence**
Cell phone battery			*1 2 3 4*
Someone's voice			*1 2 3 4*
Fossil fuels			*1 2 3 4*
Compressed springs			*1 2 3 4*
Sunshine			*1 2 3 4*
Ball sitting on top of a bookshelf			*1 2 3 4*
Wind			*1 2 3 4*

7. Provide an example for each of the following energy transformations:

   a. Gravitational to Motion:

   b. Electrical to Sound:

   c. Chemical to Motion:

   d. Radiant to Chemical:

Level of confidence: 1 2 3 4

8. Describe the difference between renewable and non-renewable energy.

Level of confidence: 1 2 3 4

9. Classify each of the energy sources listed below as renewable [R] or non-renewable [NR].

   a. <u>Natural gas:</u>
   b. <u>Petroleum:</u>
   c. <u>Coal:</u>
   d. <u>Wind:</u>
   e. <u>Hydropower:</u>
   f. <u>Solar:</u>
   g. <u>Nuclear:</u>
   h. <u>Biomass:</u>
   i. <u>Geothermal:</u>

Level of confidence: 1 2 3 4

10. The force due to gravity at the lunar surface is ________ of that on Earth.

Level of confidence: 1 2 3 4

11. What is the difference between mass and weight? Would your mass be the same on the moon as it is on Earth? Would your weight be the same?

Level of confidence: 1 2 3 4

12. On the surface of the moon, a bowling ball would hit the lunar surface [before/after/at the same as] a feather if dropped from the same height. Explain your answer.

Level of confidence: 1 2 3 4

13. The moon follows a regular repeating path that in space takes around another the Earth, called an _________.

Level of confidence: 1 2 3 4

14. The moon is the Earth's only natural _________.

Level of confidence: 1 2 3 4

15. The eight steps in the Engineering Design Process are listed below. Put them in the correct order by placing a number (1-8) in the blank next to each step.

- ____ Research the problem and identify constraints
- ____ Brainstorm possible solutions
- ____ Test and evaluate
- ____ Select the best solution and justify your choice
- ____ Communicate solutions
- ____ Re-design
- ____ Identify the problem
- ____ Construct prototype

Level of confidence: 1 2 3 4

For the next set of questions, please put an "X" in the box that most closely agrees with your answer.

Question	**5 I strongly agree**	**4 I agree**	**3 I neither agree nor disagree**	**2 I disagree**	**1 I strongly disagree**
1) I am motivated to learn about science topics in school.					
2) I am NOT motivated to learn about science topics outside of school, in my free time.					
3) I am interested in having more of my school subjects taught using video game technology.					
4) I am NOT interested in pursuing studies and/or a career in Science, Technology, Engineering, or Mathematics.					

Pre-Lesson Assessment Questions for Teachers

Name: ______________________________
Date: ______________________________
School: ______________________________
Class/Grade: ______________________________

1. What, if any, previous experiences have you had with game-based learning?

2. Are there any subjects that you want to teach using video games?

For the next set of questions, please check the box that most closely agrees with your answer.

Question	**5 I strongly agree**	**4 I agree**	**3 I neither agree nor disagree**	**2 I disagree**	**1 I strongly disagree**
1) I am likely to use game-based learning in my classroom this school year.					
2) I am NOT likely to use game-based learning in my classroom beyond this school year.					

EVALUATE: Post-Lesson Assessment Questions for Students

Name: ______________________________
Date: ______________________________
School: ______________________________
Class/Grade: ______________________________
Teacher: ______________________________

Please answer the following questions.

If the question includes a "level of confidence" indicator, then circle a number based on how sure you are about your answer using the following scale:

1: I didn't know the answer so I made my best guess.
2: I'm not sure about my answer.
3: I think my answer is correct.
4: I'm very sure that my answer is correct.

1. Energy is defined as the ability to ____________.

   Level of confidence: 1 2 3 4

2. Most energy on Earth comes, in one way or another, from _____ ______.

   Level of confidence: 1 2 3 4

3. Draw pictures that describe potential energy and kinetic energy, and then use words to describe the difference between them.

   Level of confidence: 1 2 3 4

4. Several forms of energy are listed below:

   - *Chemical*
   - *Radiant*
   - *Mechanical*
   - *Gravitational*
   - *Electrical*
   - *Motion*
   - *Sound*

For each of the following examples, list the correct form of energy and indicate whether it is an example of potential or kinetic energy by writing a "P" or a "K" in the third column:

Examples	**Form of Energy**	**Potential [P] or Kinetic [K]**	**Level of Confidence**
Cell phone battery			*1 2 3 4*
Someone's voice			*1 2 3 4*
Fossil fuels			*1 2 3 4*
Compressed springs			*1 2 3 4*
Sunshine			*1 2 3 4*
Ball sitting on top of a bookshelf			*1 2 3 4*
Wind			*1 2 3 4*

5. Provide an example for each of the following energy transformations:

Energy Transformation	**Example**	**Level of Confidence**
Gravitational to Motion		*1 2 3 4*
Electrical to Sound		*1 2 3 4*
Chemical to Motion		*1 2 3 4*
Radiant to Chemical		*1 2 3 4*

6. Describe and explain the difference between renewable and non-renewable energy.

Level of confidence: *1* *2* *3* *4*

7. Classify each of the energy sources listed below as renewable [R] or non-renewable [NR].

Energy Sources	Renewable [R] or Non-renewable [NR]?	Level of Confidence
Natural gas		*1 2 3 4*
Petroleum		*1 2 3 4*
Coal		*1 2 3 4*
Wind		*1 2 3 4*
Hydropower		*1 2 3 4*
Solar		*1 2 3 4*
Nuclear		*1 2 3 4*
Biomass		*1 2 3 4*
Geothermal		*1 2 3 4*

8. The force due to gravity at the lunar surface is ________ of that on Earth.

Level of confidence: *1* *2* *3* *4*

9. What is the difference between mass and weight? Would your mass be the same on the moon as it is on Earth? Would your weight be the same?

Level of confidence: *1* *2* *3* *4*

10. On the surface of the moon, a bowling ball would hit the lunar surface [before/after/at the same as] a feather if dropped from the same height. Explain your answer.

Level of confidence: 1 2 3 4

11. The moon follows a regular repeating path around the Earth in space called an _________.

Level of confidence: 1 2 3 4

12. The moon is the Earth's only natural _________.

Level of confidence: 1 2 3 4

13. The eight steps in the Engineering Design Process are listed below. Put them in the correct order by placing a number (1-8) in the blank next to each step.

- ____ Research problem
- ____ Brainstorm possible solutions
- ____ Test & evaluate
- ____ Select best possible solutions & justify selections
- ____ Communicate solutions
- ____ Re-design
- ____ Identify need/problem
- ____ Construct prototype

Level of confidence: 1 2 3 4

14. What does "science" mean to you?

15. Please list 3 things that you liked about this lesson:
    a)
    b)
    c)

16. Please list 3 things that you did NOT like about this lesson:
    a)
    b)
    c)

17. If you were teaching this lesson, is there anything that you would change or do differently?

18. Compared to your typical science class, was learning about science topics using Moonbase Alpha more, less, or equally as enjoyable for you? Why?

19. Was the knowledge you learned in the classroom portion of the lesson useful during your Moonbase Alpha challenge?

20. Is there anything that would have been useful for you to learn before playing Moonbase Alpha?

21. What, if anything, did playing Moonbase Alpha teach you about science that you have not learned in class?

22. What, if anything, did Moonbase Alpha teach you about teamwork?

23. What, if anything, did Moonbase Alpha teach you about the challenges related to living and working on the moon?

24. Are there any topics that you would want to have taught using video games?

For the next set of questions, please put an "X" in the box that most closely agrees with your answer.

Question	**5 I strongly agree**	**4 I agree**	**3 I neither agree nor disagree**	**2 I disagree**	**1 I strongly disagree**
1) I am motivated to learn about science topics in school.					
2) I am NOT motivated to learn about science topics outside of school, in my free time.					
3) I like science.					
4) I do NOT think I have the ability to do science.					
5) I feel that scientific exploration is important.					
6) I am interested in having more of my school subjects taught using video game technology.					
7) I am NOT interested in pursuing studies and/or a career in Science, Technology, Engineering, or Mathematics.					
8) Playing Moonbase Alpha was fun.					
9) My Moonbase Alpha team worked well together.					
10) Teamwork was NOT important to my team's success in Moonbase Alpha.					
11) Communication was NOT important to my team's success in Moonbase Alpha.					

EVALUATE: Post-Lesson Assessment Questions for Teachers

Name: ______________________________
Date: ______________________________
School: ______________________________
Class/Grade: ______________________________

1. What, if any, previous experiences have you had with game-based learning?

2. Are there any subjects that you want to teach using video games?

3. What were the difficulties of using *Moonbase Alpha* to teach this lesson?

4. What were the benefits of using *Moonbase Alpha* to teach this lesson?

5. Are there any obstacles that prevent you from using game-based learning more often in your classroom?

6. Based on your experience with *Moonbase Alpha*, are you more, less, or equally likely to use game-based learning in your classroom?

7. What did your students learn from playing *Moonbase Alpha*?

8. What would you change or do differently with this lesson?

9. Do you believe that teaching methods will be substantially different from today in 5 years? 10 years? How do you expect teaching methods to be different or the same?

For the next set of questions, please check the box that most closely agrees with your answer.

Question	**5 I strongly agree**	**4 I agree**	**3 I neither agree nor disagree**	**2 I disagree**	**1 I strongly disagree**
1) I am likely to use game-based learning in my classroom this school year.					
2) I am NOT likely to use game-based learning in my classroom beyond this school year.					
3) My students enjoyed playing *Moonbase Alpha*.					
4) *Moonbase Alpha* was NOT easy for my students to use.					
5) My students learned about teamwork while playing *Moonbase Alpha*.					

APPENDIX C: TEACHER RESOURCES

Moonbase Alpha Overview for Teachers and Answer Keys

***Moonbase Alpha* Overview for Teachers**

Moonbase Alpha was created through a partnership between NASA's Learning Technologies Program (LTP) and commercial game developers and is a single-scenario demo version of a Massively Multiplayer Online Game (MMOG) entitled *Astronaut: Moon, Mars, and Beyond*, which is to be released in 2011.

Moonbase Alpha is intended to inspire younger players to consider technical careers while engaging in a fun and challenging mission based on NASA's lunar exploration architecture.

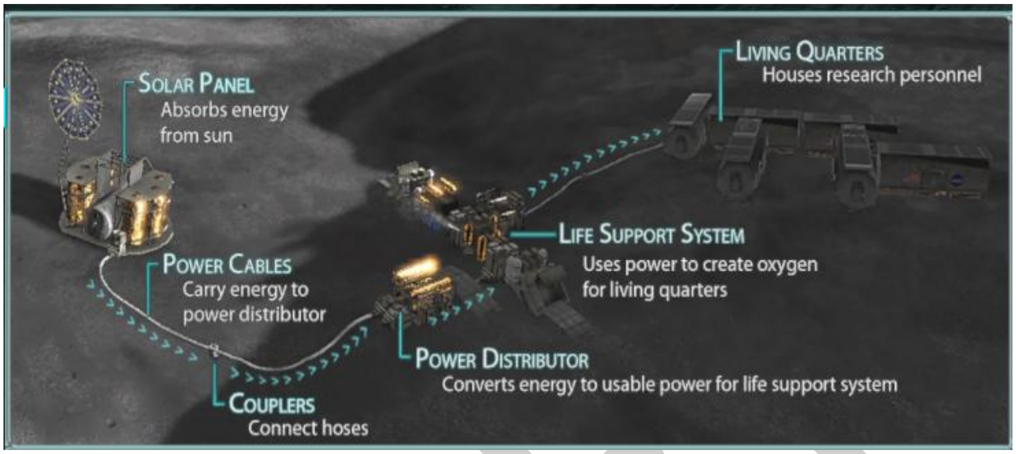
Premise:
NASA has once again landed on the lunar surface with the goals of maintaining a sustained human presence, performing research, and furthering exploration. Shortly after the return to the Moon, NASA has established a small outpost on the south pole of the Moon called *Moonbase Alpha*. Utilizing solar energy and regolith processing for materials, the Moonbase has become self-sufficient and plans for further expansion are underway.

In *Moonbase Alpha*, you assume the exciting role of an astronaut working to further human exploration and research. Returning from a research expedition, you witness a meteorite impact that cripples the life support capability of the settlement. With precious minutes ticking away, you and your team must repair and replace equipment in order to restore the oxygen production to the settlement.

Overview of the settlement:

- Solar Panels: Absorb the Sun's energy and convert it to direct current electricity using a photovoltaic material (crystalline silicon).
- Power Cables: Transfer electricity from the solar panels to the power distributor and are linked together with couplers.
- Power Distributor: Using bridge circuits, converts the electric current from the solar panels into electrical power that can be used to create oxygen. Repairing the distributor components increases its efficiency of converting energy to power, thereby providing more power to the life support system.

- Life Support System: Uses electric power to heat the lunar regolith, breaking it down into its components so that breathable oxygen can be extracted and transferred to the living quarters. Repairing the system components increases the system's efficiency, which increases the oxygen generation rate.



- Rover: Carries up to 2 people at a time, in addition to tools and equipment.
- Equipment shed: Contains tools, toolboxes, replacement equipment, and robots.
- Command center: Allows one player at a time to remotely control the rover and to view the settlement from various stationary cameras and each player's point-of-view.

Modes of play:

- Competitive: Player(s) have 25 minutes to fully restore oxygen to the living quarters
- Free play: No time limit
- Number of players:
  - 1-2 , 3-4, or 5-6 player modes
  - Differences are related to the size of the settlement and the amount of equipment that is provided
    - 1-2 players: 2 solar arrays, 1 rover, 1 equipment shed
    - 3-4 players: 3 solar arrays, 2 rovers, 1 equipment shed
    - 5-6 players: 4 solar arrays, 2 rovers, 2 equipment sheds
- Password-protected games can be created so that the game can only be accessed by a particular group.

In-game communication:

- Players are easily identified by name & color code on their space-suits
- Keyboard chat (includes a built-in system which blocks the use of curse words)

- Text-to-speech capability
- Voice chat capability

Game play:

Repairs

- Components can be repaired or replaced
- Damage levels
  - Yellow – light damage
  - Orange – moderate damage
  - Red – severe damage
  - Black – destroyed/not repairable
- Solar panels
  - Very fragile due to the fact that they are made of crystalline silicon
  - If damaged, then a solar panel cannot absorb the sun's energy
  - Panels must be un-deployed (lowered) prior to making repairs
  - Repairs are made with the welding tool
- Cables and Couplers
  - If the coupler is damaged or if there is a section of cable that is not connected to a coupler, then the energy can't be transferred beyond that point
  - Couplers must be repaired with a welding tool
  - After connecting a cable to a coupler, players much use a wrench to secure the connection
  - If the cable is not secure, then there will be a flashing yellow light on the coupler
  - Couplers that are getting power have a green light
- Power distributor and life support system
  - Cannot be accessed by people due to a hazardous coolant leak
  - Robots are used to make repairs & replacements; players need to get near the site and then deploy the robot, which they then control remotely
  - Both types of robots (welders & grabbers) will be needed
  - Fixing things in this area increases the efficiency of the conversion of energy to power (power distributor) and oxygen generation (life support system)
  - Components that need to be fixed or replaced include O_2/N_2 controllers, O_2 generators, and CO_2 filters

Rovers

- Can be driven by the person riding on the rover or remotely from the command center
- Powered by rechargeable solar batteries

Equipment shed

- Tools
  - Wrenches
  - Welding torch
  - Beacons
- Robots
  - Grabbers
  - Welders
  - Can trade between speed (for both motion & repair) and battery power
- Toolboxes
  - Can carry up to 3 tools
  - Come with a wrench & 2 welding torches
- Replacement equipment

Decisions to make before/during game play

- Strategies
  - Decide which tools, replacement parts, and/or robots to take with you
  - Decide whether to repair or replace red items
  - Decide how to efficiently dividethe work between team members
- Prioritizing – focus on repairing a complete energy flow path or focus on increasing efficiency by repairing the power distributor and life support system components
- Robot creation – tradeoff between speed & power

Information/Help:

- Equipped item
- Player list
- Time remaining (competitive mode) or time elapsed (free play)
- Percentage of oxygen restored to living quarters
- Rate of oxygen flowing to living quarters
- Chat box
- Mini-map
  - Normal: real-time overhead view of all activity
  - Schematic: energy flow (designated by purple dots), damage states, positions of players/robots/rover
- Full-screen map
  - Bring up using “M” key
  - Same information as mini-map
  - Numeric list of how many components have been repaired and how many still need to be repaired

- Help menu
    - Bring up using “F1” key
    - Controls (astronaut, rover, and robot)
    - Description of life support system & its components
    - Details about tools & repairs

Screenshots:

Hints/strategies:

1. There is no way to pause the game in competitive mode, so it's a good idea to review the information in the help menu before beginning the challenge.
2. One tool or piece of equipment can be carried at a time; the heavier the object you're carrying, the slower you move.
3. The toolbox allows you to carry more tools, but it is heavier and it requires an extra step to actually get the tool in your hand.
4. It might be useful to leave tools at various sites if you need to go elsewhere and come back.
5. There's a toolbox and a replacement coupler already sitting in between the two solar arrays.
6. Robots with more speed move from place-to-place more quickly and make repairs faster, but could be harder to control. Battery power is important because several items need to be fixed in the hazardous area.
7. If there isn't at least one working energy pathway (solar array/cable) then no oxygen can be produced, so it may be best to fix one segment first so that some oxygen starts flowing.
8. In most cases, it's quicker to replace red (critical) items than it is to repair them.
9. Players with the best mouse control should control the robots and/or do welding work (time-saver with circuit bypass).
10. One player could potentially stay at the command center and direct others & deliver rovers/equipment (shed & command are close to each other).
11. One player could potentially carry a wrench and serve as the one who re-connects all of the cabling.
12. Beacons can be used to identify areas to focus on (might save time so that each player isn't looking at the map all of the time) or meeting places (colors & names can be assigned).

Pre- and Post-Lesson Assessment Questions for Students

Answer Key

1. Energy is defined as the ability to ____________. do work

2. Most energy on Earth comes, in one way or another, from _____ ______. the sun

3. Describe the difference between potential energy and kinetic energy.

   Potential energy is stored energy (not in use). Kinetic energy is working/moving energy (in use).

4. Several forms of energy are listed below:

   - *Chemical*
   - *Radiant*
   - *Mechanical*
   - *Gravitational*
   - *Electrical*
   - *Motion*
   - *Sound*

   For each of the following examples, list the correct form of energy and indicate whether it is an example of potential or kinetic energy by writing a "P" or a "K" in the third column:

Examples	Form of Energy	Potential [P] or Kinetic [K]
Cell phone battery	Electrical	P
Someone's voice	Sound	K
Fossil fuels	Chemical	P
Compressed springs	Mechanical	P
Sunshine	Radiant	K
Ball sitting on top of a bookshelf	Gravitational	P
Wind	Motion	K

5. Provide an example for each of the following energy transformations:

   a. *Gravitational to Motion:* ball falls off of a shelf
   b. *Electrical to Sound:* talking on the phone
   c. *Chemical to Motion:* cars burn gasoline to move
   d. *Radiant to Chemical:* photosynthesis (energy from the sun's rays is converted to food energy for plants)

6. Describe the difference between renewable and non-renewable energy.

   Renewable energy can be easily replenished, while non-renewable energy exists in limited amounts and cannot be re-created.

7. Classify each of the energy sources listed below as renewable [R] or non-renewable [NR].

   a. *Natural gas:* NR
   b. *Petroleum:* NR
   c. *Coal:* NR
   d. *Wind:* R
   e. *Hydropower:* R
   f. *Solar:* R
   g. *Nuclear:* NR
   h. *Biomass:* R
   i. *Geothermal:* R

8. The force due to gravity at the lunar surface is ________ of that on Earth. 1/6

9. What is the difference between mass and weight? Would your mass be the same on the moon as it is on Earth? Would your weight be the same?

   Mass refers to the amount of material composing an object while weight refers to the force that gravity applies to that object. The mass of an object is a property of that object, and does not change regardless of the gravitational force that it is exposed to.

   For this reason, an object's mass would be the same on both the moon and on Earth. However, the weight depends on the gravitational force. For example, the weight of any object on the moon would be $1/6^{th}$ of its weight on Earth, because the Moon's gravity is $1/6^{th}$ of Earth's gravity.

10. On the surface of the moon, a bowling ball would hit the lunar surface [before/after/at the same as] a feather if dropped from the same height. Explain your answer.

On the surface of the moon, a bowling ball would hit the lunar surface **at the same time as** a feather if dropped from the same height, due to the lack of an atmosphere on the moon to impede either object. Gravity provides the same acceleration to both objects, regardless of mass, and they would therefore hit the lunar surface at the same time.

11. The moon follows a regular repeating path that in space takes around another the Earth, called an _________. orbit

12. The moon is the Earth's only natural _________. satellite

13. Below are the steps in the Engineering Design Process. Put them in the correct order by placing a number (1-8) in the blank next to each step.

- __2__ Research the problem
- __3_ Brainstorm possible solutions
- __6_ Test and evaluate
- __4_ Select the best possible solution and justify your choice
- __7_ Communicate solutions
- __8_ Re-design
- __1__ Identify the problem
- __5_ Construct prototype

EXPLORE Worksheet: The Moon

Answer Key

References:

1) Handout: Excerpts from the Lunar Nautics Educator's Guide
   (Full guide: http://www.nasa.gov/pdf/200173main_Lunar_Nautics_Guide.pdf)

2) NASA Education: Orbits
   http://www.nasa.gov/audience/forstudents/5-8/features/what-is-orbit-58.html

3) World Book at NASA [Moon]
   http://www.nasa.gov/worldbook/Moon_worldbook.html

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1. How and when was the Moon formed?

   Scientists believe the Moon was formed after a planet-sized object collided with Earth 4.6 billion years ago. As a result of the impact, a cloud of vaporized rock shot off Earth's surface and went into orbit around Earth. The cloud cooled and condensed into a ring of small, solid bodies, which then gathered together, forming the Moon.

2. The Moon follows a regular repeating path that in space takes around the Earth, called a/an _________. (orbit)

3. The Moon is the Earth's only natural _________. (satellite)

4. How do astronomers measure the tilt of a planet with respect to its axis of rotation? What is the tilt of Earth? What is the tilt of the Moon? List two consequences of the relative smallness of the Moon's tilt.

   Astronomers measure axial tilt relative to a line perpendicular to the ecliptic plane, an imaginary surface through Earth's orbit around the sun.

   Tilt of Earth: 23.5 degrees
   Tilt of the Moon: 1.5 degrees

   Consequences:

   - The Moon has no seasons.
   - Due to the smallness of the Moon's tilt, certain large peaks near the poles are always in sunlight. In addition, the floors of some craters -- particularly near the south pole -- are always in shadow.

5. How often does the Moon rotate about its own axis?

   About once every 29.5 Earth days

6. List the four phases of the Moon and describe why the Moon goes through these phases.

   Phases: new Moon, first quarter, full Moon, last quarter.

   The new Moon is when the Moon appears completely dark from Earth. This occurs when the Moon is between the Earth and the sun. The first night after a new Moon an observer from Earth can see a thin crescent of light along the Moon's eastern edge. Each subsequent night, an observer can see a larger crescent of sunlight as the terminator, the line between the dark and sunlight areas moves westward. After seven days, the observer can see half of the full Moon, commonly called a half Moon. This phase is referred to as the first quarter. About seven days later, the Moon is on the side of the Earth opposite the sun and the entire Moon appears bright. This is a full Moon. The next night the terminator appears on the western edge of the Moon. Six days later only half of the Moon is visible. This is referred to as the last quarter.

7. Identify three reasons why astronauts must wear space suits on the Moon.

   - The Moon has no atmosphere and therefore astronauts must carry their own air supply on the Moon.
   - Since the Moon has no atmosphere, the pressure of gases at the lunar surface is about 3.9 x 10^-14 pounds per square inch. The Space suit provides the astronaut with pressure required for humans to live.
   - The temperature at the lunar equator ranges from extremely low to extremely high -- from about -280 degrees F (-173 degrees C) at night to +260 degrees F (+127 degrees C) in the daytime. In some deep craters near the Moon's poles, the temperature is always near -400 degrees F (-240 degrees C). Space suits provide a temperature-controlled environment for the astronauts when they are working in space or on the lunar surface.

8. Describe one scientific reason to return to the Moon.

   - Long-term missions to the Moon can help us understand more about the formation of the solar system.
   - We can learn about the basic origins of the Moon, the physical processes shaping its surface and make astronomical observations from the Moon without the Earth's atmosphere interfering.
   - Since the Moon is believed to be formed from matter from primordial Earth, we can learn more about primordial life on Earth as well.

9. Why are some parts of the Moon more ideal for a lunar settlement than others?

- In the 1990s two robotic probes detected evidence of frozen water at both of the Moon's poles. Settlements in these areas would allow astronauts to utilize the frozen Moon water.
- Some parts of the Moon get more sunlight than others, and since solar energy is likely a primary source of power for a lunar settlement, areas with more sunlight are ideal.

EXPLORE Worksheet: Gravity

Answer Key

References:

1) NASA Education: Microgravity
   http://www.nasa.gov/audience/forstudents/5-8/features/what-is-microgravity-58.html
2) NASA Education: Orbits
   http://www.nasa.gov/audience/forstudents/5-8/features/what-is-orbit-58.html

3) World Book at NASA [Moon]
   http://www.nasa.gov/worldbook/Moon_worldbook.html

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1. What is gravity? What is microgravity?

   Gravity is the force that causes every object to pull every other object toward it. Gravity is what holds the Moon in orbit around Earth. Gravity causes Earth to orbit the sun. It keeps the sun in place in the Milky Way galaxy.

   Microgravity is the condition in which people or objects appear to be weightless. "Micro-" means "very small," so microgravity refers to the condition where gravity seems to be very small. [1]

2. The force due to gravity at the lunar surface is ________ of that on Earth.

   $1/6^{th}$ [3]

3. What is the difference between mass and weight? Would your mass be the same on the Moon as it is on Earth? Would your weight be the same?

   Mass refers to the amount of material composing an object while weight refers to the force that gravity applies to that object. The mass of an object is a property of that object, and does not change regardless of the gravitational force that it is exposed to.

   For this reason, an object's mass would be the same on both the Moon and on Earth. However, the weight depends on the gravitational force. For example, the weight of any object on the Moon would be $1/6^{th}$ of its weight on Earth, because the Moon's gravity is $1/6^{th}$ of Earth's gravity.

4. List 3 things that provide evidence of the presence of gravity in space.

   - Gravity holds the Moon in orbit around the Earth.
   - Gravity holds the Earth in orbit around the sun.
   - Gravity holds the solar system in orbit around the center of the Milky Way galaxy.
   - Gravity causes satellites and the International Space Station to orbit the Earth. [1]

5. On the surface of the Moon, a bowling ball would hit the lunar surface [before/after/at the same time as] a feather if dropped from the same height. Explain your answer.

   On the surface of the Moon, a bowling ball would hit the lunar surface **at the same time as** a feather if dropped from the same height, due to the lack of an atmosphere on the Moon to impede either object. Gravity provides the same acceleration to both objects, regardless of mass, and they would therefore hit the lunar surface at the same time.

6. How does the Moon's gravitational force impact everyday life on Earth?

   The Moon is close enough to the Earth to produce tides in the ocean. [3]

7. Identify three challenges of working in a microgravity environment such as the lunar surface.

   - Objects will float away freely unless tethered to something.
   - Normal tools such as drills may be difficult or impossible to use since they would easily spin the user in reduced gravity.
   - Working in microgravity can cause human muscles to atrophy over time, leading to weakness. Humans are also prone to nausea and other health problems in microgravity.
   - Less force can be applied to objects (such as stomping on an object or twisting open a door).

EXPLORE Worksheet: Energy

Answer Key

References:

1. World Book Student Discovery Encyclopedia at NASA – "Energy" http://www.nasa.gov/worldbook/wbkids/k_energy.html
2. California Energy Commission – "The Energy Story" http://www.energyquest.ca.gov/story/index.html
3. US Energy Information Administration - "Energy Kids" http://www.eia.doe.gov/kids/index.cfm
4. Handout: Excerpts from the Lunar Design Challenge Education Guide (pg. 85) (Full guide can be viewed at: http://www.nasa.gov/pdf/475486main_HEP_I_MS_6.pdf)

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1. Energy is defined as the ability to _________. (do work)
2. Most energy on Earth comes, in one way or another, from ________. (the sun)
3. Define potential energy and kinetic energy, and provide an example of each. *(multiple possible answers)*

   Potential energy is stored energy (not in use). Examples include chemical energy in fossil fuels, electrical energy stored in a battery, gravitational energy of an object resting on a surface at some height above the ground, mechanical energy stored in compressed springs, nuclear energy stored in the nucleus of an atom, etc. Kinetic energy is working/moving energy (in use). Examples include boiling water, rays of sunshine warming the Earth, wind, pencil rolling on a desk, etc. A girl who swings backward on a swing set has stored-up, or potential, energy at the top of her swing. After she swings down from the top, kinetic energy, or the energy of movement, swings her forward. *[1, 2, & 3]*

   <u>From the VA SOL Framework:</u> Potential energy is energy that is not "in use" and available to do work. Kinetic energy is energy that is "in use" – the energy a moving object has due to its motion. For example, moving water and wind have kinetic energy.

4. List three examples of energy transformations.
   (multiple possible answers, answers below are from [2])

   - Stored energy in a flashlight's batteries becomes light energy when the flashlight is turned on.
   - Food is stored energy. It is stored as a chemical with potential energy. When your body uses that stored energy to do work, it becomes kinetic energy.
   - If you overeat, the energy in food is not "burned" but is stored as potential energy in fat cells.
   - When you talk on the phone, your voice is transformed into electrical energy, which passes over wires (or is transmitted through the air). The phone on the other end changes the electrical energy into sound energy through the speaker.
   - A car uses stored chemical energy in gasoline to move. The engine changes the chemical energy into heat and kinetic energy to power the car.
   - A toaster changes electrical energy into heat and light energy. (If you look into the toaster, you'll see the glowing wires.)
   - A television changes electrical energy into light and sound energy.

   From the VA SOL Framework: *Heat and light can be converted into mechanical energy, chemical energy, and electrical energy and back again. The chemical energy in fossil fuels is potential energy until it is released.*

5. Describe the difference between renewable and non-renewable energy.

   Renewable energy can be easily replenished, while non-renewable energy exists in limited amounts and cannot be re-created. *(reference 3)*

   From the VA SOL Framework: *Renewable sources of energy are available on a perpetual basis and can be replenished over relatively short periods of time. Non-renewable sources of energy take very long periods of time to form and cannot be re-created once they are depleted.*

6. Classify each of the energy sources listed below as renewable [R] or non-renewable [NR].
   a. *Natural gas:* NR
   b. *Petroleum:* NR
   c. *Coal:* NR
   d. *Wind:* R
   e. *Hydropower:* R
   f. *Solar:* R
   g. *Nuclear:* NR
   h. *Biomass:* R
   i. *Geothermal:* R

7. Three of the major forms of non-renewable energy are fossil fuels. What are the three major fossil fuels and why are they called fossil fuels?

   The three major fossil fuels are coal, oil, and natural gas. All three were formed many hundreds of millions of years ago before the time of the dinosaurs - hence the name fossil fuels. *(reference 2)*
   They're called fossil fuels because they were formed over millions and millions of years by the action of heat from the Earth's core and pressure from rock and soil on the remains (or "fossils") of dead plants and creatures like microscopic diatoms. Another nonrenewable energy source is the element uranium, whose atoms we split (through a process called nuclear fission) to create heat and ultimately electricity. *[3]*

8. Compare and contrast the following energy sources in terms of their origins, how they are utilized, and the advantages/disadvantages of their use.

	Natural Gas	**Solar**	**Wind**
Origin	Buried remains of plants & animals, transformed due to pressure & heat	Energy from the sun's rays (solar radiation)	Kinetic energy of the wind, transformed into mechanical or electrical energy
Uses	Heat water and buildings, produce materials like steel and glass	Heat water and buildings, provide light, power satellites	Produce electricity
Advantages	Burns more cleanly than other fossil fuels	Produces no air or water pollution and no greenhouse gases	Produces no air or water pollution because no fuel is used to generate electricity
Disadvantages	Non-renewable, Produces carbon dioxide which is a greenhouse gas	Only works when the sun is shining	Wind speeds must be above 12-14 mph, may have a negative impact on wild bird populations

9. What source(s) of energy do you think would be ideal to use on the Moon? Why? Why would other sources of energy be less ideal?
   (answer below is from reference [4]; students' answers can be a sub-set of this)

   There are many different types of energy sources we use on a daily basis. Many people in the United States obtain their electricity from wind energy, hydroelectric dams, coal power plants, nuclear power plants, solar panels, natural gas, geothermal, and many more. When establishing a colony on the Moon, many of these alternatives are no longer possible. For instance, a hydroelectric dam would not be a good idea, because there is no water on the Moon. Solar power may be an alternative, but that would require constant solar activity. Consideration also needs to be given to the fact that all the equipment that goes to the Moon must be transported from Earth.

   Nuclear Power

   A nuclear fission reactor could fill most of the need for power. The advantage it has over a fusion reactor is that it is an already existing technology. One advantage of using a fusion reactor is that Helium-3, which is required for a type of fusion reaction, is abundant on the Moon. However, it is possible that reliable, efficient fusion reactors will not be available at the time of lunar colonization. Radioisotope thermoelectric generators could be used as backup and emergency power sources for solar-powered colonies.

   Solar Energy

   Solar energy could prove to be a relatively cheap source of power for a lunar base, as many of the raw materials needed for solar panel production can be extracted onsite. However, the long lunar night (14 Earth days) is problematic for solar power on the Moon. This might be solved by building several power plants, so that at least one of them is always in daylight. Another possibility is to build such a power plant where there is constant or near-constant sunlight, such as at the Malapert Mountain near the lunar south pole, or on the rim of Peary crater near the north pole.

EXPLORE Worksheet: Lunar Life Support Systems

Answer Key

References:

1. Handout: Excerpts from the Lunar Nautics Educator's Guide
   (Full guide: http://www.nasa.gov/pdf/200173main_Lunar_Nautics_Guide.pdf)
2. NASA Science News – "Breathing Moon Rocks"
   http://science.nasa.gov/science-news/science-at-nasa/2006/05may_Moonrocks/
3. Handout: *Moonbase Alpha* Overview

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1. Photovoltaics refers to the direct conversion of ________ into __________ at the atomic level.

   Photovoltaics is the direct conversion of light into electricity at the atomic level. *[1]*

2. From what material are the solar cells made?

   Photovoltaic or solar cells are made of silicon (sand). *[1]*

3. How do photovoltaic materials convert the sun's energy?

   Photovoltaic materials exhibit a property known as the photoelectric effect that causes them to absorb photons of light and release electrons. When these free electrons are captured, an electric current results that can be used as electricity. *[1]*

4. The life support system uses electricity and regolith to generate oxygen for the living quarters.

   a. What is lunar regolith?

      Most of the lunar surface is covered with regolith, a mixture of fine dust and rocky debris produced by meteor impacts. The regolith was produced by innumerable meteorite impacts through geologic time. Lunar regolith contains oxygen, silicon, magnesium, iron, calcium, aluminum and titanium. *([1], students' answers can be a sub-set)*

b. How can lunar regolith be used to produce oxygen?

About 40 percent of the lunar soil is oxygen, bound up in molecular silicates and metal oxides. The reason that oxygen is so abundant on the Moon is that it bonds easily to so many things. Oxygen-bonded materials are lightweight and thus float up to the surface to form the crust of a planetary body as it evolves. (Metals do not like to bond with oxygen and usually sink to the core of a planet. They are rare in the crust and precious to those living on the surface.) Oxygen can literally be cooked out of the regolith and can be used for breathable air. *([1], students' answers can be a sub-set)*
Eric Cardiff of NASA's Goddard Space Flight Center is working on a technique that heats lunar soils until they release oxygen. "It's a simple aspect of chemistry," he explains. "Any material crumbles into atoms if made hot enough." The technique is called vacuum pyrolysis--*pyro* means "fire", *lysis* means "to separate." . *([2], students' answers can be a sub-set)*

5. Describe the strategies that must be used to make repairs to each part of the life support system. What are the benefits associated with repairing each system? What challenges might your team face?
(multiple possible answers, answers below are partially from reference [3])

- Solar panels:
  - Benefits
    - Required for life support system to work. If damaged, then a solar panel cannot absorb the sun's energy.
  - Strategies
    - Repairs are made with the welding tool
    - Panels must be un-deployed (lowered) prior to making repairs
  - Challenges
    - Panels are very fragile due to the fact that they are made of crystalline silicon
- Power cables:
  - Benefits
    - If the coupler is damaged or if there is a section of cable that isn't connected to a coupler, then the energy can't be transferred beyond that point
  - Strategies
    - Couplers must be repaired with a welding tool.
    - After connecting a cable to a coupler, players much use a wrench to secure the connection.

        - If the cable is not secure, then there will be a flashing yellow light on the coupler. Couplers that are getting power have a green light.
    - Challenges
        - Making sure you have all of the necessary equipment to make repairs
- Power distributor & life support system:
    - Benefits
        - Fixing things in this area increases the efficiency of the conversion of energy to power (power distributor) and oxygen generation (life support system)
    - Strategies
        - Robots are used to make repairs & replacements; players need to get near the site and then deploy the robot, which they then control remotely
        - Both types of robots (welders & grabbers) will be needed
        - Components that need to be fixed or replaced include O2/N2 controllers, O2 generators, and CO2 filters
    - Challenges
        - Cannot be accessed by people due to a hazardous coolant leak
        - Creating the right type of robot with a good balance of speed and battery power
        - Controlling the robot remotely

6. Based on your knowledge of the life support system, what would you recommend the team's priorities be when repairing the system and why? (open-ended, multiple possible answers)

- If there isn't at least one working energy pathway (solar array/cable) then no oxygen can be produced, so fix one segment first so that some oxygen starts flowing.
- Replace red (critical) items rather than trying to repair them. Repairs could take too long.
- Use a robot with a good combination of battery power & speed to fix the power distributor and life support system.
- The toolbox allows you to carry more tools, but it's heavier and it requires an extra step to actually get the tool in your hand. It might be useful to leave tools at various sites if you need to go elsewhere and come back.
- There is no way to pause the game in competitive mode, so it's a good idea to review the information in the help menu before beginning the challenge.

- Players with the best mouse control should control the robots and/or do welding work (time-saver with circuit bypass).
- One player could potentially stay at command center and direct others & deliver rovers/equipment (shed & command are close to each other).
- One player could potentially carry a wrench and serve as the one who re-connects all of the cabling.
- Beacons can be used to identify areas to focus on (might save time so that each player isn't looking at the map all of the time) or meeting places (colors & names can be assigned).

APPENDIX D: STUDENT RESOURCES

EXPLORE Worksheets, EXTEND & EVALUATE Logbooks, & *Moonbase Alpha* Overview for Students

Moonbase Alpha Overview for Students

Moonbase Alpha was created through a partnership between NASA's Learning Technologies Program (LTP) and commercial game developers and is a single-scenario demo version of a Massively Multiplayer Online Game (MMOG) entitled *Astronaut: Moon, Mars, and Beyond*, which is to be released in 2011.

Moonbase Alpha is intended to inspire younger players to consider technical careers while engaging in a fun and challenging mission based on NASA's lunar exploration architecture.

Premise:
NASA has once again landed on the lunar surface with the goals of maintaining a sustained human presence, performing research, and furthering exploration. Shortly after the return to the Moon, NASA has established a small outpost on the south pole of the Moon called *Moonbase Alpha*. Utilizing solar energy and regolith processing for materials, the Moonbase has become self-sufficient and plans for further expansion are underway.

In *Moonbase Alpha*, you assume the exciting role of an astronaut working to further human exploration and research. Returning from a research expedition, you witness a meteorite impact that cripples the life support capability of the settlement. With precious minutes ticking away, you and your team must repair and replace equipment in order to restore the oxygen production to the settlement.

Check out these *Moonbase Alpha* websites for more information:

NASA's *Moonbase Alpha* homepage

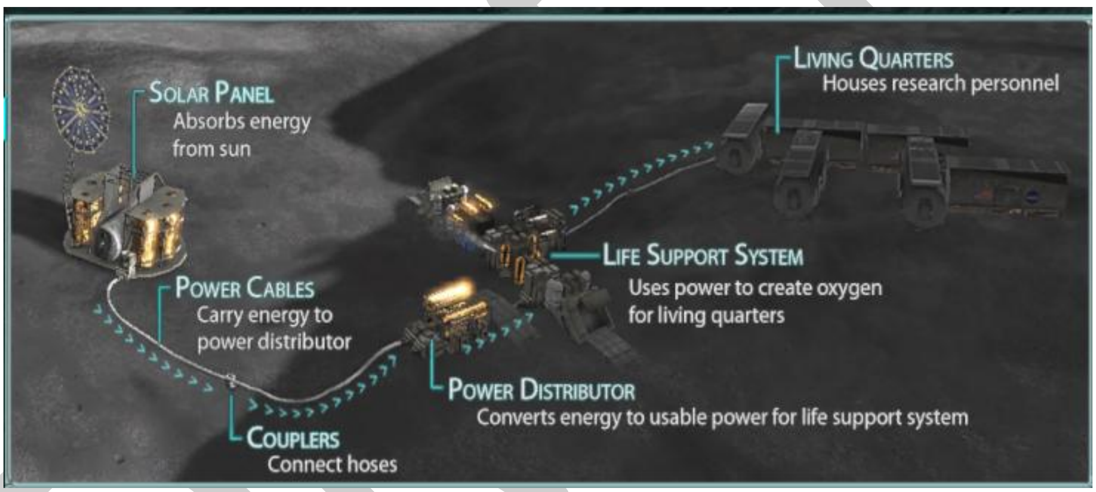
Virtual Heroes' *Moonbase Alpha* homepage

NASA Games YouTube Channel

NASA Games on Facebook

Overview of the settlement:

- Solar Panels: Absorb the Sun's energy and convert it to direct current electricity using a photovoltaic material (crystalline silicon).
- Power Cables: Transfer electricity from the solar panels to the power distributor and are linked together with couplers.
- Power Distributor: Using bridge circuits, converts the electric current from the solar panels into electrical power that can be used to create oxygen. Repairing the distributor components increases its efficiency of converting energy to power, thereby providing more power to the life support system.
- Life Support System: Uses electric power to heat the lunar regolith, breaking it down into its components so that breathable oxygen can be extracted and transferred to the living quarters. Repairing the system components increases the system's efficiency, which increases the oxygen generation rate.



- Rover: Carries up to 2 people at a time, in addition to tools and equipment.
- Equipment shed: Contains tools, toolboxes, replacement equipment, and robots.
- Command center: Allows one player at a time to remotely control the rover and to view the settlement from various stationary cameras and each player's point-of-view.

Modes of play:

- Competitive: Player(s) have 25 minutes to fully restore oxygen to the living quarters
- Free play: No time limit
- Number of players:
  - 1-2 , 3-4, or 5-6 player modes
  - Differences are related to the size of the settlement and the amount of equipment that is provided

        - 1-2 players: 2 solar arrays, 1 rover, 1 equipment shed
        - 3-4 players: 3 solar arrays, 2 rovers, 1 equipment shed
        - 5-6 players: 4 solar arrays, 2 rovers, 2 equipment sheds

Game play:

<u>Repairs</u>

- Components can be repaired or replaced
- Damage levels
    - Yellow – light damage
    - Orange – moderate damage
    - Red – severe damage
    - Black – destroyed/not repairable
- Solar panels
    - Very fragile due to the fact that they are made of crystalline silicon
    - If damaged, then a solar panel cannot absorb the sun's energy
    - Panels must be un-deployed (lowered) prior to making repairs
    - Repairs are made with the welding tool
- Cables and Couplers
    - If the coupler is damaged or if there is a section of cable that is not connected to a coupler, then the energy can't be transferred beyond that point
    - Couplers must be repaired with a welding tool
    - After connecting a cable to a coupler, players much use a wrench to secure the connection
    - If the cable is not secure, then there will be a flashing yellow light on the coupler
    - Couplers that are getting power have a green light
- Power distributor and life support system
    - Cannot be accessed by people due to a hazardous coolant leak
    - Robots are used to make repairs & replacements; players need to get near the site and then deploy the robot, which they then control remotely
    - Both types of robots (welders & grabbers) will be needed
    - Fixing things in this area increases the efficiency of the conversion of energy to power (power distributor) and oxygen generation (life support system)
    - Components that need to be fixed or replaced include O2/N2 controllers, O2 generators, and CO2 filters

Rovers

- Can be driven by the person riding on the rover or remotely from the command center
- Powered by rechargeable solar batteries

Equipment shed

- Tools
    - Wrenches
    - Welding torch
    - Beacons
- Robots
    - Grabbers
    - Welders
    - Can trade between speed (for both motion & repair) and battery power
- Toolboxes
    - Can carry up to 3 tools
    - Come with a wrench & 2 welding torches
- Replacement equipment

EXPLORE Worksheet: The Moon

Name: ______________________________
Date: ______________________________
School: ______________________________
Class/Grade: ______________________________
Teacher: ______________________________

Instructions: Answer the following questions using the references listed at the end of this worksheet.

1. How and when was the Moon formed?

2. The Moon follows a regular repeating path that in space takes around the Earth, called a/an _________.

3. The Moon is the Earth's only natural _________.

4. What is the tilt of the Moon? What is the tilt of Earth? List two consequences of the relative smallness of the Moon's tilt.

5. How often does the Moon rotate about its own axis?

6. List the four phases of the Moon and describe why the Moon goes through these phases.

7. Identify three reasons why astronauts must wear space suites on the Moon.

8. Describe one scientific reason to return to the Moon.

9. Why are some parts of the Moon more ideal for a lunar settlement than others?

References:

1) Handout: Excerpts from the Lunar Nautics Educator's Guide
   (Full guide: http://www.nasa.gov/pdf/200173main_Lunar_Nautics_Guide.pdf)

2) NASA Education: Orbits
   http://www.nasa.gov/audience/forstudents/5-8/features/what-is-orbit-58.html

3) World Book at NASA [Moon]
   http://www.nasa.gov/worldbook/Moon_worldbook.html

EXPLORE Worksheet: Gravity

Name: ______________________________
Date: ______________________________
School: ______________________________
Class/Grade: ______________________________
Teacher: ______________________________

Instructions: Answer the following questions using the references listed at the end of this worksheet.

1. What is gravity? What is microgravity?

2. The force due to gravity at the lunar surface is _________ of that on Earth.

3. What is the difference between mass and weight? Would your mass be the same on the Moon as it is on Earth? Would your weight be the same?

4. List 3 things that provide evidence of the presence of gravity in space.

5. On the surface of the Moon, a bowling ball would hit the lunar surface [before/after/at the same as] a feather if dropped from the same height. Explain your answer.

6. How does the Moon's gravitational force impact everyday life on Earth?

7. Identify three challenges of working in a microgravity environment such as the lunar surface.

References:

1) NASA Education: Microgravity
http://www.nasa.gov/audience/forstudents/5-8/features/what-is-microgravity-58.html
2) NASA Education: Orbits
http://www.nasa.gov/audience/forstudents/5-8/features/what-is-orbit-58.html

3) World Book at NASA [Moon]
http://www.nasa.gov/worldbook/Moon_worldbook.html

EXPLORE Worksheet: Energy

Name: ______________________________
Date: ______________________________
School: ______________________________
Class/Grade: ______________________________
Teacher: ______________________________

Instructions: Answer the following questions using the references provided at the end of this worksheet.

1. Energy is defined as the ability to _____________.
2. Most energy on Earth comes, in one way or another, from _________.
3. Define potential energy and kinetic energy, and provide an example of each.

4. List three examples of energy transformations.

5. Describe the difference between renewable and non-renewable energy.

6. Classify each of the energy sources listed below as renewable [R] or non-renewable [NR].
    a. *Natural gas:*
    b. *Petroleum:*
    c. *Coal:*
    d. *Wind:*
    e. *Hydropower:*
    f. *Solar:*
    g. *Nuclear:*
    h. *Biomass:*
    i. *Geothermal:*

7. Three of the major forms of non-renewable energy are fossil fuels. What are the three major fossil fuels and why are they called fossil fuels?

8. Compare and contrast the following energy sources in terms of their origins, how they are utilized, and the advantages/disadvantages of their use.

	Natural Gas	**Solar**	**Wind**
Origin			
Uses			
Advantages			
Disadvantages			

9. What source(s) of energy do you think would be ideal to use on the Moon? Why? Why would other sources of energy be less ideal?

References:

1. World Book Student Discovery Encyclopedia at NASA – "Energy"
   http://www.nasa.gov/worldbook/wbkids/k_energy.html

2. California Energy Commission – "The Energy Story"
   http://www.energyquest.ca.gov/story/index.html

3. US Energy Information Administration - "Energy Kids"
   http://www.eia.doe.gov/kids/index.cfm

4. Handout: Excerpt from the Lunar Design Challenge Education Guide
   (Full guide: http://www.nasa.gov/pdf/475486main_HEP_I_MS_6.pdf)

EXPLORE Worksheet: Lunar Life Support Systems

Name: ______________________________
Date: ______________________________
School: ______________________________
Class/Grade: ______________________________
Teacher: ______________________________

Instructions: Answer the following questions using the references listed at the end of this worksheet.

1. Photovoltaics refers to the direct conversion of ________ into __________ at the atomic level.

2. From what material are the solar cells made?

3. How do photovoltaic materials convert the sun's energy?

4. The life support system uses electricity and regolith to generate oxygen for the living quarters.

    a. What is lunar regolith?

    b. How can lunar regolith be used to produce oxygen?

5. Describe the strategies that must be used to make repairs to each part of the life support system. What are the benefits associated with repairing each system? What challenges might your team face?

    - Solar panels:

    - Power cables:

    - Power distributor & life support system:

6. Based on your knowledge of the life support system, what would you recommend the team's priorities be when repairing the system and why?

References:

1. Handout: Excerpts from the Lunar Nautics Educator's Guide
   (Full guide: http://www.nasa.gov/pdf/200173main_Lunar_Nautics_Guide.pdf)

2. NASA Science News – "Breathing Moon Rocks"
   http://science.nasa.gov/science-news/science-at-nasa/2006/05may_Moonrocks/

3. Handout: *Moonbase Alpha* Overview

EXTEND Mission Logbook: Pre-Mission Strategy

Name: ______________________________
Date: ______________________________
School: ______________________________
Class/Grade: ______________________________
Teacher: ______________________________

Instructions: Work with your team to develop a strategy to restore oxygen to the lunar habitat and record your thoughts. Record your strategy below.

Some items to consider include:

1. Use of in-game items (help menus, rovers, tool box, replacement parts, robots, etc.)
2. Prioritization and decisions between making repairs vs. replacements
3. Crew resource management – what tools are necessary to complete a job, how to use the rover efficiently, assignment of tasks to team members based on skill set (such as welding and robot operation), etc.

EXTEND Mission Logbook: Post-Mission Debrief #1

Name: ______________________________
Date: ______________________________
School: ______________________________
Class/Grade: ______________________________
Teacher: ______________________________

Instructions: Answer the following questions based on your experience playing *Moonbase Alpha* in competitive mode with your team.

1. What approach did your team take and why?

2. Were you successful at completing the mission? If yes, discuss what made your team successful. If no, what were some of the challenges that prevented your team from completing the mission?

3. Within your team, discuss both technical and team oriented challenges and record your thoughts below.

EVALUATE Mission Logbook: Post-Mission Debrief #2

Name: ______________________________
Date: ______________________________
School: ______________________________
Class/Grade: ______________________________
Teacher: ______________________________

Instructions: Answer the following questions based on your experience playing *Moonbase Alpha* in competitive mode with your team.

1. What did your team do differently the 2nd time you played?

2. Were you successful at completing the mission? If yes, discuss what made your team successful. If no, what were some of the challenges that prevented your team from completing the mission?

3. How did your team assign roles?

4. What team member qualities were valuable in making your team work well together?