Lesson 2: Let's Design

Lesson Snapshot

Overview

Big Idea: Design is a creative planning process that leads to useful products and systems.

Purpose of Lesson: This lesson will guide students in using the engineering design process to design a plant growth chamber for use on the lunar surface.

Lesson Duration: Two hours.

Activity Highlights

Engagement: Students use the ***KWL Chart*** to enhance their understanding of the requirements for a plant growth chamber for use on the lunar surface.

Exploration: Students read the design brief for the ***Design Brief***. The teacher leads a discussion about the requirements and answers questions.

Explanation: The teacher shows students videos and/or images of the new vehicles designed for the Constellation Program. The teacher demonstrates design processes, including the development of two-dimensional and three-dimensional representations of design solutions.

Extension: Students, working in design teams, follow the engineering design process to develop two-dimensional and three-dimensional representations of a plant growth chamber for use on the lunar surface. Students select an approach to build.

Evaluation: Student knowledge, skills and attitudes are assessed using selected response items and rubrics for class participation and design development.

Lesson 2: Overview

Lesson Duration

- Two hours.

Standards/Benchmarks

Technology: Standards for Technological Literacy *(ITEA, 2000/2002)*

- Students will develop an understanding of the attributes of design. (ITEA/*STL* 8)
  - Design is a creative planning process that leads to useful products and systems. (ITEA/*STL* 8E)
- Students will develop an understanding of engineering design. (ITEA/*STL* 9)
  - Brainstorming is a group problem-solving design process in which each person in the group presents his or her ideas in an open forum. (ITEA/*STL* 9G)
  - Modeling, testing, evaluating and modifying are used to transform ideas into practical solutions. (ITEA/*STL* 9H)
- Students will develop the abilities to apply the design process. (ITEA/*STL* 11)
  - Specify criteria and constraints for the design. (ITEA/*STL* 11I)
  - Test and evaluate the design in relation to pre-established requirements, such as criteria and constraints and refine as needed. (ITEA/*STL* 11K)
- Students will develop the abilities to use and maintain technological products and systems. (ITEA/*STL* 12)
  - Use computers and calculators in various applications. (ITEA/*STL* 12J)

Science: Benchmarks for Science Literacy (*AAAS, 1993*)

- The Nature of Technology/Technology and Science (AAAS 3A)
  - Engineers, architects and others who engage in design and technology use scientific knowledge to solve practical problems, but they usually have to take human values and limitations into account as well. (AAAS-3A)

Mathematics: Principles and Standards for School Mathematics *(NCTM, 2000)*

- Measurement
  - Solve problems involving scale factors, using ratio and proportion.
  - Develop and use formulas to determine the circumference of circles and the area of triangles, parallelograms, trapezoids and circles and develop strategies to find the area of more-complex shapes.
- Representation
  - Use representations to model and interpret physical, social and mathematical phenomena.

Learning Objectives

Students will:

1. Explain that design is a creative planning process that leads to useful products and systems.
2. Identify criteria and constraints related to the design and development of a plant growth chamber on the lunar surface.
3. Apply the engineering design process to solve a problem.
4. Identify and describe the major steps in the engineering design process.
5. Explain that brainstorming is a group problem-solving design process in which each person in the group presents his or her ideas in an open forum.
6. Use criteria and constraints related to the design and development of a plant growth chamber to brainstorm possible design solutions.

7. Analyze possible solutions to the design challenge.
8. Select an approach to the design challenge.

Student Assessment Tools and/or Methods

1. Selected Response Items

		Column I	Column II
	1.	Defining the problem	a. thinking of and recording ideas
	2.	Brainstorming a solution	b. adjusting your solution based on evaluation
	3.	Generating ideas	c. limits placed on a design
	4.	Criteria	d. identifying needs and wants.
	5.	Constraints	e. identifying pros and cons of multiple solutions
	6.	Exploring possibilities	f. requirements for a design solution
	7.	Selecting an approach	g. creating accurate drawings of multiple possible solutions
	8.	Prototype	h. choosing a solution based on criteria and constraints
	9.	Evaluating the design	i. testing the design and collecting data
	10.	Refining the design	j. a working model of a design solution

Key: **1d**, **2a**, **3g**, **4f**, **5c**, **6e**, **7h**, **8j**, **9i**, **10b**

2. Rubric for Engineering Design Process (Lesson 2 Extension Activity—**Lunar Plant Growth Chamber Design Steps**)

Category	Below Target	At Target	Above Target
Defining the Problem	Rephrases the problem with limited clarity.	Rephrases the problem clearly.	Rephrases the problem clearly and precisely.
Identifying Criteria and Constraints	Does not restate the criteria clearly and fails to identify constraints.	Restates the criteria clearly and identifies several constraints.	Restates the criteria clearly and precisely and identifies many constraints.
Brainstorming a Solution (Individual)	Contributes few and/or implausible ideas or no ideas.	Contributes a plausible idea.	Contributes multiple, plausible ideas.
Generating Ideas	Contributes implausible ideas. Produces incomplete sketches. Does not present a concept.	Contributes one plausible idea. Produces marginally accurate pictorial and orthographic sketches of design concepts.	Contributes multiple plausible ideas. Produces accurate pictorial and orthographic sketches of design concepts.
Exploring Possibilities	Inadequately analyzes the pluses and minuses of a variety of possible solutions.	Satisfactorily analyzes the pluses and minuses of a variety of possible solutions.	Thoroughly analyzes the pluses and minuses of a variety of possible solutions.
Selecting an Approach	Selection of solution is not based on consideration of criteria and constraints.	Selects a promising solution based on criteria and constraints.	Selects a promising solution based on a thorough analysis criteria and constraints.
Making a Model or Prototype	Prototype meets the task criteria to a limited extent.	Prototype meets the task criteria.	Prototype meets the task criteria in insightful ways.
Testing and Evaluating the Design	Testing and evaluation processes are inadequate.	Testing and evaluation processes are adequate for refining the problem solution.	Testing and evaluation processes are innovative.
Refining the Design	Refinement based on testing and evaluation is not evident.	Refinements made based on testing and evaluation results.	Significant improvement in the design is made based on prototype testing and evaluation.

3. Optional Rubric for Class Participation
   Teacher's Note: Teachers may choose to use this rubric as a way to assess students, with or without making it a basis for student grades.

Category	Below Target	At Target	Above Target
Preparation	Rarely prepared. Minimal effort to participate.	Prepared for class. Attempts to answer teacher-generated questions.	Well prepared for class. Attempts to answer teacher-generated questions and adds additional information to class when relevant.
Curiosity	Rarely demonstrates curiosity.	Usually demonstrates curiosity.	Consistently demonstrates curiosity.
Motivation for Learning	Rarely demonstrates motivation for learning.	Usually demonstrates motivation for learning.	Consistently demonstrates motivation for learning.
Use of Time	Gives up easily; is not engaged. Has difficulty remaining on task.	Makes good use of class time to work on assignments and projects.	Makes excellent use of class time to work on assignments and projects.
Teacher Comment			

Resource Materials

Print Materials

1. *Teachers and students investigating plants in ppace: A teacher's guide with activities for life sciences* (EG-1997-02-113-HQ). (1997). ASIN: B000H48XM6. Retrieved July 6, 2007 from http://education.nasa.gov/edprograms/core/home/index.html
2. *Fundamentals of space biology: research on cells, animals and plants in space* New York: Springer.
3. Pierce, A. & Karwatka, D. (1999). *Introduction to technology*. New York: Glencoe/ McGraw-Hill, (pp. 157-180).

Audiovisual Materials

1. *NASA connect - functions and statistics - International Space Station - Up to us*. (n.d.). Retrieved July 6, 2007 from http://www.open-video.org/details.php?videoid=6311
2. *JFK moon speech at Rice University*. (1962, November 12). Retrieved from http://www1.jsc.nasa.gov/er/seh/ricetalk.htm

Internet Sites

1. Wilson, J. (Ed.). (2007 February 23). *Camping on the moon will be a far out experience*. (n.d.). Retrieved July 6, 2007 from http://www.nasa.gov/mission_pages/exploration/mmb/inflatable-lunar-hab.html
2. *The Constellation Program – Videos, images and descriptions of the new spacecraft systems*. (n.d.). Retrieved March 1, 2007 from http://www.nasa.gov/mission_pages/constellation/main/index.html

Lesson 2: Modified 5-E Lesson Plan

Engagement

1. Students, working individually, use the ***KWL Chart*** to enhance their understanding of the requirements for a plant growth chamber to be used on the lunar surface.

Exploration

1. The teacher distributes the ***Design Brief***.
2. Student volunteers read the design brief aloud to the rest of the class.
3. Students return to their design teams from the previous lesson and compare their list of criteria to that presented in the design brief.
4. The teacher asks students to compare and contrast the two sets of criteria.
5. The teacher discusses and clarifies information in the design brief as needed.
6. Students complete the KWL process as they learn answers to their questions.

Explanation

1. The teacher discusses the Constellation Program (the new vehicles and systems that will likely be used to transport humans to the moon and beyond) with the students. The teacher shows the video ***Ares*** "To the Moon and Beyond" is one of several videos and images that can be used to show the new systems. "Camping on the Moon" is a section that shows a proposed design for a moon outpost. (Location can be found in the References section p.29)
2. The teacher explains that:
    - Invention and innovation relate to the development of new products, processes and systems.
    - Brainstorming is a group problem-solving process in which each person in the group presents his or her ideas in an open forum. Ideas are to be recorded but not evaluated during this step. Drawings and lists are common ways to record design ideas.
    - Modeling, testing, evaluating and modifying are used to transform ideas into practical solutions.
3. The teacher reviews the basic steps of the ***Engineering Design Process***.
    - Identify the problem.
    - Identify criteria and constraints (requirements).
    - Brainstorm possible solutions.
    - Generate ideas—develop multiple solutions.
    - Explore possibilities—create a pro/con chart for each idea.
    - Select an approach—based on requirements and pro/con chart.
    - Make a model or prototype.
    - Test and evaluate the design.
    - Refine the design.
4. The teacher asks students to draw and label three examples of a flat surface with an area of ten square feet. The teacher may choose to draw one example on the board to help students get started. The teacher demonstrates methods for solutions that involve the following steps:
    - Rectangles
    - Circles
    - Triangles
    - Combinations of the shapes above

Extension

Students work with their design teams to select an approach for a lunar plant growth chamber. This includes identifying the problem, identifying requirements, brainstorming, generating ideas and exploring possibilities. Students document their work using the resource, ***Lunar Plant Growth Chamber Design Steps.***

Evaluation

Student knowledge, skills and attitudes are assessed using selected response items and rubrics for class participation and brief constructed responses. The rubrics are presented in advance of the activities to familiarize students with the expectations and performance criteria. They are also reviewed during the activities to guide students in the completion of assignments. The teacher may wish to develop a collection of annotated exemplars of student work based on the rubrics. The exemplars serve as benchmarks for future assessments and may be used to familiarize students with the criteria for assessment.

Enrichment

Students may read about and see more images of the components of the Constellation Program at http://www.nasa.gov/mission_pages/constellation/main/index.html. Students may be asked to identify old and current technology being applied to this new endeavor as well as the new systems being developed. Students may also be asked to identify mission components as expendable versus reusable.

Lesson 2: Lesson Preparation

Teacher Planning

The laboratory-classroom should provide a flexible, resource-rich learning environment that includes areas for lectures and demonstrations, small group meetings and research activities. The teacher adapts the learning environment based on the requirements of the unit or lesson. For this lesson, areas for lecture and demonstration, design, small group meetings and fabrication activities should be readied.

Tools/Materials/Equipment

- Chalkboard or overhead projector
- Computer with Internet access, LCD projector and speakers
- Sketching and Drawing Sheets (optional)
- Teacher rubric included in lesson

Classroom Safety and Conduct

1. Students demonstrate respect and courtesy for the ideas expressed by others in the class.
2. Students show respect and appreciation for the efforts of others.
3. Students use tools and equipment in a safe manner and assume responsibility for their safety as well as for the safety of others.

KWL Chart

Requirements for a design include such factors as the desired elements and features of a product or system or the limits that are placed on the design. These are called **criteria** (what do we want?) and **constraints** (what are our limits?).

Technological designs typically have to meet requirements to be successful. These requirements usually relate to the purpose or function of the product or system. Other requirements, such as size and cost, describe the limits of the design. (ITEA, 2000/2002).

Complete the following chart: Requirements for a plant growth chamber on the moon.

What I Know	What I Would Like To Learn	What I Learned

Design Brief: Track 1

NASA engineers have developed a plan for a lunar outpost. The station will be established near the lunar South Pole and be inhabited by two astronauts on a three-month mission. The available space on the lunar lander is extremely limited; therefore, all items must be designed to take up minimal space. The mission requires that a plant growth chamber be used to supplement the diet of the astronauts during their stay.

Challenge: Design and develop a plant growth chamber that will be used by astronauts to grow lettuce and tomatoes as dietary supplements on the moon.

Requirements:

1. The lunar plant growth chamber must be able to provide a growing area of 10 square feet and have a delivery volume of three cubic feet or less.
2. The lunar plant growth chamber may expand to any volume desired.
3. The lunar plant growth chamber must be a separate, independent structure from the lunar station.
4. Placement and access to the chamber must make it possible for astronauts to tend to and harvest crops without venturing out onto the lunar surface.
5. The lunar plant growth chamber must have systems that provide light, temperature control, water and nutrient delivery and power.
6. The lunar plant growth chamber may link to the lunar station to get power.

Procedure:

1. Students, working in groups of two to four, will use the engineering design process to develop a prototype of a lunar growth chamber.

2. Student groups will:
   a. Assign a project manager.
   b. Discuss the problem and take notes.
   c. Individually sketch ideas and list possible solutions.
   d. Select a few ideas and develop detailed drawings.
   e. Evaluate each idea by identifying pros and cons.
   f. Select an approach that meets the criteria and constraints.
   g. Construct a prototype.
   h. Evaluate and refine the prototype.

3. Make an oral presentation to the class describing the use and function of the lunar plant growth chamber. Students should use their model to demonstrate how it would work and point out important features.

Materials for Prototype:

- Cardboard and/or foam core
- Tape
- Cool melt glue guns
- Plastic wrap
- Waxed paper
- Craft sticks or various size wood scraps
- Various hardware: nuts and bolts, screws, nails, paperclips
- Scissors
- Any other modeling materials deemed safe and appropriate by the teacher.

Assessment:

Student work and participation will be assessed both during and after this activity.

Rubric for Class Participation

Category	Below Target	At Target	Above Target
Preparation	Rarely prepared. Minimal effort to participate.	Prepared for class. Attempts to answer teacher-generated questions.	Well prepared for class. Attempts to answer teacher-generated questions and adds additional information to class when relevant.
Curiosity	Rarely demonstrates curiosity.	Usually demonstrates curiosity.	Consistently demonstrates curiosity.
Motivation for Learning	Rarely demonstrates motivation for learning.	Usually demonstrates motivation for learning.	Consistently demonstrates motivation for learning.
Use of Time	Gives up easily; is not engaged. Has difficulty remaining on task.	Makes good use of class time to work on assignments and projects.	Makes excellent use of class time to work on assignments and projects.

Engineering Design Process

The engineering design process involves a series of steps that lead to the development of a new product or system. In this design challenge, students are to complete each step and document their work as they develop their lunar plant growth chamber. The students should be able to:

Identify the Problem – Students should state the challenge problem in their own words. Example: How can I design a _____ that will _____?

Identify Criteria and Constraints – Students should specify the design requirements (criteria). Example: Our growth chamber must have a growing surface of ten square feet and have a delivery volume of three cubic feet or less. Students should list the limits on the design due to available resources and the environment (constraints). Example: Our growth chamber must be accessible to astronauts without the need for leaving the spacecraft.

Brainstorm Possible Solutions – Each student in the group should sketch his or her own ideas as the group discusses ways to solve the problem. Labels and arrows should be included to identify parts and how they might move. These drawings should be quick and brief.

Generate Ideas – In this step, each student should develop two or three of his or her ideas more thoroughly. They should create new drawings that are orthographic projections (multiple views) and isometric drawings (three-dimensional depiction). These are to be drawn neatly using rulers to draw straight lines and to make parts proportional. Parts and measurements should be labeled clearly.

Explore Possibilities – The developed ideas should be shared and discussed among the team members. Students should record pros and cons of each design idea directly on the paper next to the drawings.

Select an Approach – Students should work in teams and identify the design that appears to solve the problem the best. Students should write a statement that describes why they chose the solution. This should include some reference to the criteria and constraints identified above.

Make a Model or Prototype – Students will construct a full-size or scale model based on their drawings. The teacher will help them identify and acquire appropriate modeling materials and tools. See the design brief for a sample list.

Refine the Design – Students will examine and evaluate their prototypes or designs based on the criteria and constraints. Groups may enlist students from other groups to review the solution and help identify changes that need to be made. Based on criteria and constraints, teams must identify any problems and proposed solutions.

Lunar Plant Growth Chamber Design Steps: Track 1

Group Members: _____

Product Name: _____

Refer to the assessment rubric when completing each of these sections.

Identify the problem: _____

_____

Criteria: _____

_____

Constraints: _____

_____

Brainstorm and Generate Ideas: Each group member should list and sketch ideas on separate sheets of paper and attach to this form. Develop your best idea. Draw and label the parts.

Explore Possibilities: Make a pros and cons chart next to each of the best ideas and list advantages and disadvantages of the design.

Select an approach. Explain your selection. _____

_____

Make a Model or Prototype: Consult with your teacher about available resources and tools.

How did you test and evaluate your solution? _____

_____

_____

Refine the design. _____

_____

_____

_____

Lunar Plant Growth Chamber Design Steps

Assessment Instrument – Engineering Design Process

Category	Below Target	At Target	Above Target
Defining the Problem	Rephrases the problem with limited clarity.	Rephrases the problem clearly.	Rephrases the problem clearly and precisely.
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Testing and Evaluating the Design	Testing and evaluation processes are inadequate.	Testing and evaluation processes are adequate for refining the problem solution.	Testing and evaluation processes are innovative.
Refining the Design	Refinement based on testing and evaluation is not evident.	Refinements made based on testing and evaluation results.	Significant improvement in the design is made based on prototype testing and evaluation.

Lunar Plant Growth Chamber Design Steps: Track 2

Group Members: _____

Product Name: _____

Refer to the assessment rubric when completing each of these sections.

Identify the problem: _____

_____

Criteria: _____

_____

Constraints: _____

_____

Brainstorm and Generate Ideas: Each group member should list and sketch ideas on separate sheets of paper and attach to this form. Develop your best idea. Draw and label the parts.

Explore Possibilities: Make a pros and cons chart next to each of the best ideas and list advantages and disadvantages of the design.

Select an approach. Explain your selection. _____

_____

How did you test and evaluate your solution? _____

_____

_____

Refine the design. _____

_____

_____

_____

Lunar Plant Growth Chamber Design Steps

Assessment Instrument – Engineering Design Process

Category	Below Target	At Target	Above Target
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