HS

Engineering By Design

Advancing Technological Literacy

A Standards-Based Program Series

Lunar Plant Growth Chamber

Human Exploration Project
STS–118 Design Challenge

A Standards-Based High School Unit Guide

Lunar Plant Growth Chamber

Design, Build and Evaluate (Lessons 1-4)

Design and Evaluate (Lessons 1-3)

International Technology Education Association
Center to Advance the Teaching of Technology & Science

Inspiration + Innovation + Discovery = Future

NASA Engineering byDesign™ ITEA CATTS

Preface

Design Challenge: Lunar Plant Growth Chamber
A Standards-Based High School Unit

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The ITEA-CATTS Human Exploration Project (HEP)
People, Education and Technology

In May 2005, ITEA was funded by the National Aeronautics and Space Administration (NASA) to develop curricular units for Grades K-12 on Space Exploration. The units focus on aspects of the themes that NASA Engineers and Scientists—as well as future generations of explorers—must consider, such as Energy and Power, Transportation and Lunar Plant Growth Chambers (the STS-118 Design Challenges). Moreover, the units are embedded within a larger model program for technology education known as Engineering byDesign™.

The Human Exploration Project (HEP) units have several common characteristics. All units:

- Are based upon the Technological Literacy standards (ITEA, 2000/2002).
- Coordinate with Science (AAAS, 1993) and Mathematics standards (NCTM, 2000).
- Utilize a standards-based development approach (ITEA, 2005).
- Stand alone and coordinate with ITEA-CATTS Engineering byDesign™ curricular offerings.
- Reflect a unique partnership between NASA scientists and engineers and education professionals.
- Incorporate leading-edge insight and practical experiences for students on how NASA works and plans.

These unit guides are designed to be practical and user-friendly. ITEA welcomes feedback from users in the field as we continually refine these curricular products, ensuring that the content remains as dynamic as the technological world in which we live. Please email ebd@iteaconnect.org or call 703-860-2100.

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Design Challenge: Lunar Plant Growth Chamber (LPGC)
A Standards-Based High School Unit

Unit Overview

Design is a creative problem-solving process. In this unit, students will design and build a lunar plant growth chamber using the engineering design process.

This Design Challenge has been written with two tracks in mind. Track 1 provides a more comprehensive learning experience, and teachers are encouraged to consider exploring this alternative, perhaps working with other teachers in the school to provide students with resources and a laboratory-classroom with the necessary equipment.

> ***Big Idea***
> *The engineering design process is a comprehensive, valuable tool that can be used to provide solutions to complex challenges, on Earth and beyond.*

- 1: The Design, Build and Evaluate Challenge is a twelve-to-eighteen day challenge for those teachers and students who have the resources available to build a larger model with operational subsystems. Teachers need to determine what tools and materials are available to students and whether students will build a full-sized or scaled-down version of the LPGC. This extension continues after the Preliminary Design Review (PDR) in Lesson 3 with the students constructing their working prototype and presenting it at the Critical Design Review (CDR) in Lesson 4.
- 2: The Design and Evaluate Challenge is a five-to-seven day challenge. It requires students to design and build a small model of a Lunar Plant Growth Chamber (LPGC). This challenge ends with Lesson 3, culminating with the Preliminary Design Review (PDR). *Teacher's Note*: Big ideas should be made explicit to students by writing them on the board and/or reading them aloud.

Standards

Technology: Standards for Technological Literacy (*STL*) *(ITEA, 2000/2002)*
- Students will develop an understanding of the attributes of design. (ITEA/*STL* 8)
- Students will develop an understanding of engineering design. (ITEA/*STL* 9)
- Students will develop the abilities to apply the design process. (ITEA/*STL* 11)

Science: Benchmarks for Science Literacy *(AAAS, 1993)*
- The Nature of Technology/Technology and Science (AAAS 3A)
- The Nature of Technology/Design and Systems (AAAS 3B)
- The Living Environment/Flow of Matter and Energy (AAAS 5E)

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

Benchmarks

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

- Design problems are seldom presented in a clearly defined form. (ITEA/*STL* 8I)
- The design needs to be continually checked and critiqued and the ideas of the design must be refined and improved. (ITEA/*STL* 8J)
- Requirements of a design, such as criteria, constraints and efficiency, sometimes compete with each other. (ITEA/*STL* 8K)
- Engineering design is influenced by personal characteristics, such as creativity, resourcefulness and the ability to visualize and to think abstractly. (ITEA/*STL* 9K)
- Refine a design by using prototypes and modeling to ensure quality, efficiency and productivity of the final product. (ITEA/*STL* 11O)
- Evaluate the design solution using conceptual, physical and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed. (ITEA/*STL* 11P)

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

- Technological problems often create a demand for new scientific knowledge, and new technologies make it possible for scientists to extend their research in new ways or to undertake entirely new lines of research. (AAAS 3A)
- In designing a device or process, thought should be given to how it will be manufactured, operated, maintained, replaced and disposed of and who will sell, operate and take care of it. The costs associated with these functions may introduce yet more constraints on the design. (AAAS 3B)
- The more parts and connections a system has, the more ways it can go wrong. Complex systems usually have components to detect, back up, bypass or compensate for minor failures. (AAAS 3B)
- To reduce the chance of system failure, performance testing is often conducted using small-scale models, computer simulations, analogous systems or just the parts of the system thought to be least reliable. (AAAS 3B)
- The chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways. At each link in a food web, some energy is stored in newly-made structures, but much is dissipated into the environment as heat. Continual input of energy from sunlight keeps the process going. (AAAS 5E)

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

- Use visualization, spatial reasoning and geometric modeling to solve problems (NCTM Geometry)

Purpose of Unit

In this unit, students will perform research on plant requirements and apply the engineering design process to create designs for lunar plant growth chambers.

Unit Objectives

Lesson 1: Introduction to STS-118 Mission and the Design Challenge

Note: For each objective below, T represents technology or ITEA/*STL* standards; M represents mathematics or NCTM standards; S represents science or AAAS standards. Standards are listed above.

Students will:

- Explain how problems are seldom presented in a clearly defined form. (T 8I)
- Explain that engineering design is influenced by personal characteristics, such as creativity, resourcefulness and the ability to visualize and to think abstractly. (T 9K)
- Describe how technological problems often create a demand for new scientific knowledge and new technologies make it possible for scientists to extend their research in new ways or to undertake entirely new lines of research. (S 3A)
- Describe how to analyze characteristics and properties of two- and three-dimensional geometric shapes. (M Geometry)
- Describe how to use visualization, spatial reasoning and geometric modeling to solve problems. (M Geometry)
- Contribute to a group endeavor by offering useful ideas, supporting the efforts of others and focusing on the task.
- Actively participate in group discussions, ideation exercises and debates.

Lesson 2: Choosing Plant Species

Students will:

- Explain how problems are seldom presented in a clearly defined form. (T 8I)
- Explain that requirements of a design, such as criteria, constraints and efficiency, sometimes compete with each other. (T 8K)
- Explain that the chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways. At each link in a food web, some energy is stored in newly-made structures, but much is dissipated into the environment as heat. (S 5E)
- Contribute to a group endeavor by offering useful ideas, supporting the efforts of others and focusing on the task.
- Actively participate in group discussions, ideation exercises and debates.

Lesson 3: Designing the Plant Growth Chamber

Students will:

- Explain that a design needs to be continually checked and critiqued and the ideas of the design must be refined and improved. (T 8J)
- Explain that engineering design is influenced by personal characteristics, such as creativity, resourcefulness and the ability to visualize and to think abstractly. (T 9K)
- Describe how to evaluate the design solution using conceptual, physical and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed. (T 11P)
- Describe how technological problems often create a demand for new scientific knowledge and new technologies make it possible for scientists to extend their research in new ways or to undertake entirely new lines of research. (S 3A)
- Explain that when designing a device or process, thought should be given to how it will be manufactured, operated, maintained, replaced and disposed of and who will sell, operate and take care of it. The costs associated with these functions may introduce yet more constraints on the design. (S 3B)

- Explain that the more parts and connections a system has, the more ways it can go wrong. Complex systems usually have components to detect, back up, bypass or compensate for minor failures. (S 3B)
- Explain that to reduce the chance of system failure, performance testing is often conducted using small-scale models, computer simulations, analogous systems or just the parts of the system thought to be least reliable. (S 3B)
- Contribute to a group endeavor by offering useful ideas, supporting the efforts of others and focusing on the task.
- Actively participate in group discussions, exercises and debates.

Lesson 4: Building the Plant Growth Chamber

Students will:

- Describe how to refine a design by using prototypes and modeling to ensure quality, efficiency and productivity of the final product. (T 11O)
- Describe how to evaluate the design solution using conceptual, physical and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed. (T 11P)
- Explain that when designing a device or process, thought should be given to how it will be manufactured, operated, maintained, replaced and disposed of and who will sell, operate and take care of it. The costs associated with these functions may introduce yet more constraints on the design. (S 3B)
- Explain that the more parts and connections a system has, the more ways it can go wrong. Complex systems usually have components to detect, back up, bypass or compensate for minor failures. (S 3B)
- Explain that to reduce the chance of system failure, performance testing is often conducted using small-scale models, computer simulations, analogous systems or just the parts of the system thought to be least reliable. (S 3B)
- Work safely and accurately with a variety of tools, machines and materials.
- Actively participate in group discussions, ideation exercises and debates.

Student Assessment Tools and/or Methods

- A ***Unit Pre- and Post-Test*** is provided that includes questions from each lesson. It represents the knowledge assessment component for each lesson, but it may be used as a pre-assessment tool.
- Assessment for each lesson includes a quiz, and rubrics will be used for group work and/or the research, analysis and presentation.

Teacher Preparation and Resources

Teacher preparation for this unit includes the following:

- Review the first three lessons and the additional "build" lesson at the end of the Challenge.
- Review the Vision for Space Exploration and the Ares launch vehicles (***Ares*** video).
- Review NASA's Exploration Systems Architecture Study (http://science.hq.nasa.gov/kids/Earth.html and http://www.nasa.gov/mission_pages/exploration/news/ESAS_report.html).
- Gather references and compile a list of suggested Internet sites to visit. As students discover good references, Internet sites, films/documentaries, etc., the teacher should add these to the list to develop a data base.
- Research other experiments where plants were grown on the space shuttle, Mir and the International Space Station (ISS).

- Discuss with other teachers what students are studying in their classes, including science, mathematics and technology education classes, and how those concepts could be related to this challenge.
- Review teaching methodologies used in Lessons one through four.
- Copy the following handouts and resource sheets for each student:

  Lesson 1

  - ***Design Challenge Brief***

  Growth Chamber Plant List

  - ***Engineering Design Process***

  Lesson 2

  - ***Top Five Plant List Worksheet***

- Decide how big the student prototypes will be. This will be determined by the availability of modeling materials. If students will be required to build scale models, a short lesson on scale (ex. 1:4, 1:2) may be required.

Lesson 1: Introduction to STS-118 Mission and the Design Challenge

Lesson Snapshot

Overview

Big Idea: When humans begin to live away from Earth, they will have to grow some of their own food.

Teacher's Note: Big ideas should be made explicit to students by writing them on the board and/or reading them aloud.

Purpose of Lesson: This lesson enables students to describe the need for life science research on the International Space Station and the moon.

Lesson Duration: Two hours.

Activity Highlights

Engagement: Students research the STS-118 mission including Educator Astronaut, Barbara Morgan. They search for information concerning the crew, their mission and the shuttle's payload. In a couple of sentences, they report back to the class what they found.

Exploration: As a class, students discuss this question: "If I had a greenhouse, how big would it be and what type of plants would I grow in it?" They list these plants on the board or on a large chart. Students will refer back to this list in the ***Extension*** phase of this lesson.

Explanation: The teacher explains:

- The Vision for Space Exploration.
- How the STS-118 mission fits into this plan.
- Barbara Morgan's role in the mission.
- How problems are seldom presented in a clearly-defined form.
- That engineering design is influenced by personal characteristics, such as creativity, resourcefulness and the ability to visualize and to think abstractly.
- How transportation services and methods have led to a population that is regularly on the move.
- The ***Design Challenge Brief***.

Extension: Working as a class, students examine their list of plants and describe both negative and positive characteristics of their selections. They list these on the ***Growth Chamber Plant List*** worksheet. They may need to perform additional research to add other species to their list. They will need to consider the limited amount of space they will have in their growth chambers.

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

Lesson 1: Overview

Lesson Duration

- Two hours.

Standards/Benchmarks

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

- Understanding the attributes of design. (ITEA/*STL* 8)
    - Design problems are seldom presented in a clearly defined form. (ITEA/*STL* 8I)
- Understanding engineering design. (ITEA/*STL* 9)
    - Engineering design is influenced by personal characteristics, such as creativity, resourcefulness and the ability to visualize and to think abstractly. (ITEA/*STL* 9K)

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

- The Nature of Technology/Technology and Science (AAAS 3A)
    - Technological problems often create a demand for new scientific knowledge, and new technologies make it possible for scientists to extend their research in new ways or to undertake entirely new lines of research.

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

- Geometry
    - Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships.
    - Use visualization, spatial reasoning and geometric modeling to solve problems.

Learning Objectives

Note: For each objective below, T represents technology or ITEA/*STL* standards; M represents mathematics or NCTM standards; S represents science or AAAS standards. Standards are listed above.

Students will:

1. Explain how problems are seldom presented in a clearly defined form. (T 8I)
2. Explain that engineering design is influenced by personal characteristics, such as creativity, resourcefulness and the ability to visualize and to think abstractly. (T 9K)
3. Describe how technological problems often create a demand for new scientific knowledge, and new technologies make it possible for scientists to extend their research in new ways or to undertake entirely new lines of research. (S 3A)
4. Describe how to analyze characteristics and properties of two- and three-dimensional geometric shapes. (M Geometry)
5. Describe how to use visualization, spatial reasoning and geometric modeling to solve problems. (M Geometry)
6. Contribute to a group endeavor by offering useful ideas, supporting the efforts of others and focusing on the task.
7. Actively participate in group discussions, ideation exercises and debates.

Student Assessment Tools

1. Quiz (***Unit Pre- and Post-Test***)

2. Optional Rubric for Group Work
   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
Participation	Seldom participated. Did very little work.	Cooperative. Did his/her part of the work. Often offered useful ideas.	Was always willing to do more. Routinely offered useful ideas.
Reliability	Did not have work done on time. Did not show up when the group met.	Group members could count on him/her.	Went beyond what was expected of him/her.
Attitude	Did not support group members. Did not share information. Had little interest in success of the group.	Supported efforts of others. Served to facilitate rather than disrupt the group work.	Listened to and shared ideas with others. Was very self directed.

3. Assessment Totals

Element	Criteria	Points Possible	Earned Assessment Self / Teacher
Quiz	As per above		
Group Work	As per above		

Resource Materials

Print Materials

1. The STS-118 Education Resources can found by searching www.nasa.gov/sts118.

Internet Sites

1. *International space station research summary through expedition 10.* (2006). Retrieved July 6, 2007 from http://ston.jsc.nasa.gov/collections/TRS

Required Knowledge and Skills

Students should have the ability to research topics related to space and biological experiments on the space shuttle and the International Space Station.

Lesson 1: Modified 5-E Lesson Plan

Engagement

1. The teacher divides the class into four groups and explains that each group will have ten minutes to search the Internet for information about specific, separate topics. They will then have a few minutes to compile their information before they report back to the class.

   - Group 1 will search for information about the STS-118 crew.
   - Group 2 will search for information about the STS-118 mission.
   - Group 3 will search for information about the STS-118 payload.
   - Group 4 will search for information about the STS-118 mission specialist, Barbara Morgan.

2. A spokesperson from each group has one minute to report to the class on the results of the research.

Exploration

1. As a class, students discuss this question: If I had a greenhouse, how big would it be, and what type of plants would I grow in it? Students list these plants on the board or on a large chart. Students will refer back to this list in the **Extension** phase of this lesson.

Explanation

The teacher explains:

1. The teacher facilitates a brief class discussion about the future of space exploration, including the potential for extended missions on the lunar surace.
2. The teacher reviews student research from the **Engagement** Activity and explains further, as necessary:
   - NASA's goal of completing the International Space Station (ISS), retiring the space shuttle, developing and flying the Ares rockets and Orion spacecraft and going to the moon and beyond.
   - How the STS-118 mission fits into this plan. Examples include helping to complete the ISS by delivering a truss, resupplying the station crew with food, water, air, etc. and contributing to the station's science mission. The payload included a small plant growth chamber intended to remain on the station through Expedition 15.
   - STS-118 was the first flight for NASA's educator astronaut, Barbara Morgan.
   - The ISS is a test bed for technologies needed to fly to the moon and beyond. It is also a test bed to help the United States gain valuable, long duration space mission experience.

2. The teacher explains:
   - New space travel and launch methods will result in a population that is regularly traveling into space.
   - As governments and commercial ventures fly increasing numbers of people into space for longer periods of time, a way must be found to grow some of the food that will be needed.

3. The teacher explains:
   - Unrestrained objects in a spacecraft can "float" and become lost and/or cause damage to equipment.

- Plant growth chambers are devices that were developed to contain plants and provide for their needs without interfering with other spacecraft equipment.
- Different plants have different needs. The technological problem of designing chambers to meet these needs creates a demand for new scientific knowledge and new technologies. This often results in scientists' extending their research in new ways.

4. The teacher facilitates a discussion on size and shape:
    - Plant growth chambers can come in many sizes and shapes depending on where they will be installed. There may be more space for a plant growth chamber on the lunar surface compared to the International Space Station; however, a chamber for the moon will need to take up less volume on the transport from Earth to the moon. A simple mathematical formula to calculate volume is: length x width x height (v=lwh).

5. The teacher guides students to analyze the characteristics and properties of two- and three-dimensional shapes and use visualization, spatial reasoning and geometric modeling to solve problems.

6. The teacher distributes the ***Design Challenge Brief*** and explains the design challenge and the process of design:
    - This challenge requires students to design a lunar plant growth chamber (LPGC). It will be used to grow food that will supplement the food brought from Earth by future astronauts. When humans begin to stay in space for long periods of time, it will be cost prohibitive for all supplies to be launched from Earth.
    - Some supplies will need to be manufactured/grown in situ. It is generally accepted that lunar colonists will not be able to grow all the food needed for long-duration stays. LPGCs will provide some fresh edible plants to help make long stays more palatable for the crew.
    - Criteria and constraints will help determine the design for the LPGC, however problems are seldom presented in a clearly defined form. Some criteria and constraints will be specified, while others will only be revealed through research. A technological solution can be thought of as a system of subsystems. Criteria and constraints help to determine which subsystems are needed to make a system function properly. Subsystems must not interfere with each other but must work in harmony with each other. Plant requirements will dictate additional criteria and constraints for the solution, which will determine needed subsystems to make the solution function properly. As an example, the system known as an automobile has a criteria that requires it to stop, which results in a breaking subsystem. The breaking subsystem must not interfere with other subsystems.
    - There are many solutions to a problem. Engineering design is influenced by personal characteristics of the designer, such as creativity, resourcefulness and the ability to visualize and to think abstractly.

Extension

Working as a class, students examine their lists of plants and describe both negative and positive characteristics of their selections. They list these on the ***Growth Chamber Plant List***. Students may need to perform additional research in order to add other species to their list. They also need to consider the limited amount of space they will have in their growth chambers.

Enrichment

1. Students can research additional life science missions aboard the shuttle, Mir and the ISS to discover the types of plants that have already been grown in space.
2. Students can search their homes for boxes and containers of varying shapes and sizes that can be brought into school. A short activity where students try to "nest" as many containers inside each other as possible will reinforce the lesson about three-dimensional geometric shapes.

Evaluation

1. Student knowledge, skills and attitudes are assessed using selected response items.
2. A rubric is provided for class participation.

Lesson 1: Lesson Preparation

Teacher Planning

1. Students should have access to information-gathering and research equipment.
2. Student seating should facilitate both small group and whole class discussions

Tools/Materials/Equipment

- Research materials
- Computers with Internet access
- Printers
- Presentation equipment
- See also the ***Design Challenge Brief*** in Appendix
- Worksheet: ***Growth Chamber Plant List*** in Appendix

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.

Lesson 2: Choosing Plant Species

Lesson Snapshot

Overview

Big Idea: A lunar plant growth chamber must provide all the basic requirements to sustain plant life.

Purpose of Lesson: This lesson enables students to identify various plant species that are suitable for lunar plant growth and their requirements.

Lesson Duration: One hour.

Activity Highlights

Engagement: Students inspect the list of plants with their positive and negative characteristics from Lesson 1 and select five plants they would like to study further.

Exploration: With a partner, students research the plants they have selected to determine the plants requirements for healthy growth.

Explanation: The teacher explains:

- That the moon has 1/6 the gravity of Earth, no atmosphere and may have water (ice) at the poles. Some elements can be found in the rocks and regolith, but there are no nutrients in the regolith.
- Due to limited space, the plant species with the most edible parts (least waste) would be desirable. Like people, some plant species are more compatible with certain species and less compatible with others.
- The plants selected may have special requirements concerning temperature, light, radiation protection, etc.

Extension: Working with their partners, students analyze each plant's requirements for survival. They select three species that will be placed in their growth chamber.

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

Lesson 2: Overview

Lesson Duration

- One hour.

Standards/Benchmarks

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

- Students will develop an understanding of the attributes of design. (ITEA/*STL* 8)
  - Design problems are seldom represented in a clearly defined form. (ITEA/*STL* 8E)
  - Requirements of a design, such as criteria, constraints and efficiency, sometimes compete with each other. (ITEA/*STL* 8K)

Science: Benchmarks for Science Literacy (AAAS, 1993)

- The Living Environment/Flow of Matter and Energy (AAAS 5E)
  - The chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways. At each link in a food web, some energy is stored in newly made structures but much is dissipated into the environment as heat. Continual input of energy from sunlight keeps the process going.

Learning Objectives

Note: For each objective below, T represents technology or ITEA/*STL* standards; M represents mathematics or NCTM standards; S represents science or AAAS standards. Standards are listed above.

Students will:

1. Explain how problems are seldom presented in a clearly defined form. (T 8I)
2. Explain that requirements of a design, such as criteria, constraints and efficiency, sometimes compete with each other. (T 8K)
3. Explain that the chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways. At each link in a food web, some energy is stored in newly made structures, but much is dissipated into the environment as heat. (S 5E)
4. Contribute to a group endeavor by offering useful ideas, supporting the efforts of others and focusing on the task.
5. Actively participate in group discussions, ideation exercises and debates.

Student Assessment Tools

1. Optional Rubric for Group Work
   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
Participation	Seldom participated. Did very little work.	Cooperative. Did his/her part of the work. Often offered useful ideas.	Was always willing to do more. Routinely offered useful ideas.
Reliability	Did not have work done on time. Did not show up when the group met.	Group members could count on him/her.	Went beyond what was expected of him/her.
Attitude	Did not support group members. Did not share information. Had little interest in success of the group.	Supported efforts of others. Served to facilitate rather than disrupt the group work.	Listened to and shared ideas with others. Was very self-directed.

2. Assessment Instrument – Research/Analysis

Category	Below Target	At Target	Above Target
Variety of Sources	Used very few or insufficient varied sources.	Used multiple sources with multiple perspectives.	Used many sources with a variety of view points.
Documentation	Offered little or inadequate documentation.	All sources were documented properly.	Documentation was well developed and referenced.
Reflection	Analysis showed little effort.	Analysis was thorough and well thought out.	Analysis was exceptionally well thought out and showed keen insight.

3. Assessment Totals

Element	Criteria	Points Possible	Earned Assessment Self / Teacher
Quiz	As per above		
Group Work	As per above		
Research Analysis			

Resource Materials

Internet Sites

1. *Teaming up on space plants*. (n.d.). Retrieved January 14, 2007 from http://science.nasa.gov/headlines/y2001/ast10may_1.html
2. *Lettuce and LEDs: shedding new light on space farming*. (n.d.). Retrieved January 14, 2007 from http://www.space.com/businesstechnology/technology/light_farming_010926.html

Required Knowledge and Skills

Students should have the ability to research topics related to space and biological experiments on the space shuttle and the International Space Station.

Lesson 2: Modified 5-E Lesson Plan

Engagement

1. The teacher briefly reviews Lesson 1 activities.
2. Students inspect the list of plants with their positive and negative characteristics from the **Extension** activity in Lesson 1 and select five plants they would like to study further.

Exploration

With a partner, students research the plants they have selected to determine the requirements for healthy growth (***Top Five Plant List Worksheet***). Students may wish to add the plants they discovered through their research that have been tested in space already, either on the shuttle, Mir or the ISS.

Explanation

1. The teacher explains:
    - The moon has 1/6 the gravity of Earth, no atmosphere, and it may have water ice at the poles. Some elements can be found in the rocks and regolith (lunar soil), but there are no nutrients in the regolith.
    - Due to limited space, the plant species with the most edible parts (least waste) would be desirable. Like people, some plant species are more compatible with certain species and less compatible with others.
    - The plants selected may have special requirements for such things as temperature, light, radiation protection, etc.
2. Students explain and defend their reasons for selecting LPGC crops.
3. The teacher facilitates a discussion on the life process, specifically inputs (requirements for growth) and unanticipated outputs (results of the growth process). Talking points include:
    - The chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways. At each link in a food web, some energy is stored in newly made structures, but much is dissipated into the environment as heat.
    - Problems are seldom presented in a clearly defined form. The original challenge did not address this new problem of heat buildup. Will solving this unexpected problem still meet or compete with the criteria, constraints and efficiency of the LPGC?
4. Consider human nutritional needs (FDA minimum daily requirements) and nutritional content of the different plants.

Extension

1. Student plant lists from the **Exploration** activity may list five or more species. Working in teams, students analyze each plant's requirements for survival to discover those plants that are most compatible. Students may need to conduct additional research using the Internet.
2. Students select two species that will be placed in their growth chamber.
3. Each team reports to the class, describing the species they have selected, why they were selected and any special requirements that will need to be designed into the growth chamber.

Enrichment

1. Students may wish to germinate seeds from their selected species and grow them in class in order to record baselines for comparison, should they decide to grow these species in their chambers. This is done under regular Earth conditions (i.e. sunlight, potting soil, daily watering).
   Teacher's Note: Registering to implement the STS-118 Design Challenge includes the opportunity to obtain space-flown cinnamon basil seeds to grow in the completed plant growth chamber.
2. Students may wish to repeat the above experiment, changing only one variable to replicate a condition that will be present in their LPGC (i.e., different wave lengths of light, limited light, nutrient rich water/hydroponic system, high/low pH of the growth medium, etc.).

Evaluation

1. Student knowledge, skills and attitudes are assessed using selected response items from the post test.
2. Rubrics are provided for group work and research/analysis.

Lesson 2: Lesson Preparation

Teacher Planning

1. Students should have access to information-gathering and research equipment.
2. Students should have room for small group and whole class discussions.

Tools/Materials/Equipment

- Research materials
- Computers with Internet access
- Printers
- Worksheet: ***Top Five Plant List Worksheet***

Lesson 3: Designing the Plant Growth Chamber

Lesson Snapshot

Overview

Big Idea: The design of technological devices requires the consideration of limitations, trade-offs and many iterations before a final design can be selected.
Teacher's Note: Big ideas should be made explicit to students by writing them on the board and/or reading them aloud.

Purpose of Lesson: This lesson enables students to design a technological device that will meet certain requirements and to present that design for peer review.

Lesson Duration: Two to four hours.

Activity Highlights

Engagement: Students list all the subsystems they need to design in order to meet the requirements of their selected plant species.

Exploration: Students search the Internet for descriptions, sketches, drawings, etc. of proposed lunar habitats, greenhouses and other structures.

Explanation: The teacher explains:

- Mechanical subsystems may be required to circulate air, water and nutrients.
- Possible methods of shipping growth chamber parts to the lunar surface (collapsible, inflatable, "some assembly required").
- The Preliminary Design Review will require a presentation to the rest of the class and should include the design and all the evidence that supports that design (charts, graphs, drawings, pictures, PowerPoint®, etc.).
- The student will justify all parts of their designs during the PDR.

Extension: Students design their growth chambers. Their designs should include drawings and/or pictures with dimensions, graphs, charts and other visual aids students feel are necessary. Each set of partners present their designs to the class in a presentation called the Preliminary Design Review (PDR).

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

Lesson 3: Overview

Lesson Duration

- Two to four hours.

Standards/Benchmarks

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

- Understanding the attributes of design. (ITEA/*STL* 8)
  - The design needs to be continually checked and critiqued. And the ideas of the design must be refined and improved. (ITEA/*STL* 8J)
- Understanding engineering design. (ITEA/*STL* 9)
  - Engineering design is influenced by personal characteristics, such as creativity, resourcefulness and the ability to visualize and to think abstractly. (ITEA/*STL* 9K)
- Abilities to apply the design process. (ITEA/*STL* 11)
  - Evaluate the design solution using conceptual, physical and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed. (ITEA/*STL* 11P)

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

- The Nature of Technology/Technology and Science (AAAS 3A)
  - Technological problems often create a demand for new scientific knowledge and new technologies make it possible for scientists to extend their research in new ways or to undertake entirely new lines of research.
- The Nature of Technology/Design and Systems (AAAS 3B)
  - In designing a device or process, thought should be given to how it will be manufactured, operated, maintained, replaced and disposed of and who will sell, operate and take care of it. The costs associated with these functions may introduce yet more constraints on the design.
  - The more parts and connections a system has, the more ways it can go wrong. Complex systems usually have components to detect, back up, bypass or compensate for minor failures.
  - To reduce the chance of system failure, performance testing is often conducted using small-scale models, computer simulations, analogous systems or just the parts of the system thought to be least reliable.

Learning Objectives

Note: For each objective below, T represents technology or ITEA/*STL* standards; M represents mathematics or NCTM standards; S represents science or AAAS standards. Standards are listed above.

Students will:

1. Explain that a design needs to be continually checked and critiqued, and the ideas of the design must be refined and improved. (T 8J)
2. Explain that engineering design is influenced by personal characteristics, such as creativity, resourcefulness and the ability to visualize and to think abstractly. (T 9K)
3. Describe how to evaluate the design solution using conceptual, physical and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed. (T 11P)
4. Describe how technological problems often create a demand for new scientific knowledge, and new technologies make it possible for scientists to extend their research in new ways or to undertake entirely new lines of research. (S 3A)

5. Explain that the more parts and connections a system has, the more ways it can go wrong. Complex systems usually have components to detect, back up, bypass or compensate for minor failures. (S 3B)
6. Explain that to reduce the chance of system failure, performance testing is often conducted using small-scale models, computer simulations, analogous systems or just the parts of the system thought to be least reliable. (S 3B)

Student Assessment Tools

1. Optional Rubric for Group Work
   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
Participation	Seldom participated. Did very little work.	Cooperative. Did his/her part of the work. Often offered useful ideas.	Was always willing to do more. Routinely offered useful ideas.
Reliability	Did not have work done on time. Did not show up when the group met.	Group members could count on him/her.	Went beyond what was expected of him/her.
Attitude	Did not support group members. Did not share information. Had little interest in success of the group.	Supported efforts of others. Served to facilitate rather than disrupt the group work.	Listened to and shared ideas with others. Was very self directed.

2. Assessment Instrument – Research/Analysis

Category	Below Target	At Target	Above Target
Variety of Sources	Used very few or insufficiently varied sources.	Used multiple sources with multiple perspectives.	Used many sources with a variety of view points.
Documentation	Offered little or inadequate documentation.	All sources were documented properly.	Documentation was well developed and referenced.
Reflection	Analysis showed little effort.	Analysis was thorough and well thought out.	Analysis was exceptionally well thought out and showed keen insight.

3. Assessment Instrument – Presentation

Category	Below Target	At Target	Above Target
Organization	Presentation was not well organized and was hard to follow.	Presentation was well organized and easy to follow.	Presentation was exceptionally well organized and flowed very well.
Creativity	Presentation was not very creative and was somewhat boring.	Presentation was creative, showing a good deal of planning.	Presentation was extremely creative, showing that a good deal of thought went into preparation.
Feedback	Audience did not participate in the presentation.	Audience was attentive to the presentation and participated when asked.	Audience was extremely interested and asked many questions.

4. Assessment Totals

Element	Criteria	Points Possible	Earned Assessment Self / Teacher
Quiz	As per above		
Group Work	As per above		
Research Analysis	As per above		
Feedback	As per above		

Resource Materials

Internet Sites

1. *Teaming up on space plants*. (n.d.). Retrieved January 4, 2007 from http://science.nasa.gov/headlines/y2001/ast10may_1.html
2. *Solar growth chambers for NASA*. (n.d.). Retrieved January 4, 2007 from http://ag.arizona.edu/pubs/general/resrpt1998/nasa.html
3. *Education payload operations: Kit C plant growth chambers (EPO-Kit-C)*. (n.d.). Retrieved January 4, 2007 from http://exploration.nasa.gov/programs/station/EPO-Kit-C.html
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8. *The aerospace catalyst experiences for students (ACES) project*. Retrieved July 28, 2007 from http://laspace.lsu.edu/aces/Presentations.html

Required Knowledge and Skills

- Students should have a concept of scale, 1:2, 1:4.
- Students should know the metric system of measurement.
- Students should have the ability to sketch simple designs.

Lesson 3: Modified 5-E Lesson Plan

Engagement

1. Students review their notes from Lesson 1, especially the concept of subsystems.
2. Students list all the subsystems they need to design in order to meet the requirements of their selected plant species.

Exploration

Students search the Internet for descriptions, sketches and drawings of proposed lunar habitats, greenhouses and other structures

Explanation

The teacher provides students with the resources ***Engineering Design Process***. Students will participate in a discussion of the following::

- Engineering design is influenced by personal characteristics, such as creativity, resourcefulness and the ability to visualize and to think abstractly.
- In designing a device or process, thought should be given to how it will be manufactured, operated, maintained, replaced and disposed of and who will sell, operate and take care of it. The costs associated with these functions may introduce yet more constraints on the design.
- Evaluating the design solution includes conceptual, physical and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.
- Mechanical subsystems may be required to circulate air, water and nutrients.
- A design needs to be continually checked and critiqued, and the ideas of the design must be refined and improved. Complex systems usually have components to detect, back up, bypass or compensate for minor failures.
- There are several possible methods of shipping growth chamber parts to the lunar surface (collapsible, inflatable, "some assembly required").
- The Preliminary Design Review (PDR) will require a presentation to the rest of the class. The PDR is a technical review that ensures that the project will meet criteria and constraints, cost, schedule, risk and other requirements. The PDR includes performance specifications for subsystems, cost analysis and a schedule with milestones. The PDR document includes the design and all the evidence that supports that design (charts, graphs, drawings, pictures, PowerPoints®, paper/cardboard models, etc.).

Extension

Teacher's Note: Students will use their ***Engineering Design Process*** worksheets. Using these resources, the students are responsible for engaging in the engineering design process, including identifying the problem and the criteria and constraints of the challenge—based, in part, on the choices they made in selecting the plants.

1. Students design their growth chambers. Their designs include drawings and/or pictures with dimensions, graphs, charts, models and other visual aids they feel are necessary.
2. Students build a scale model of the plant growth chamber designed above with a detailed explanation.
3. Each team presents their designs to the class in a presentation called the Preliminary Design Review or PDR.

Enrichment

1. The teacher can arrange an additional PDR for the students that would include engineers, scientists, greenhouse managers and other interested individuals from the local community.
2. Working as a class, students examine geometric shapes and sizes based on achieving maximum plant production utilizing a minimal amount of space. (Further investigation of selected plants and their sizes will be needed to determine the size and shape of the growth chamber.)

Evaluation

1. Student knowledge, skills and attitudes are assessed using selected response items.
2. Rubrics are provided for group work and presentation.

Lesson 3: Lesson Preparation

Teacher Planning

1. Students should have access to information-gathering and research equipment.
2. Students should have room for small group and whole class discussions.
3. Students should have tables large enough to construct charts, models, etc.

Tools/Materials/Equipment

- Research materials
- Computers with Internet access
- Printers
- Rulers
- Art knives and/or scissors
- Poster board, tag board and/or cardboard
- Hot glue and glue guns
- Masking tape and/or packing tape

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 wear eye protection and work safely with knives, scissors and hot glue guns.

Lesson 4: Building the Plant Growth Chamber

Lesson Snapshot

Overview

Note to Teacher: This is the Build and Evaluate extension to the original Challenge and may take an additional seven to eleven class periods to complete. It is intended for those teachers and students who have the resources to build a larger model with operational subsystems. Teachers will need to determine:

- What tools and materials are available to the students.
- Will the students be limited to available materials or will they be allowed to bring materials from home.
- Will the school budget allow additional materials to be purchased and how much money will each group be allowed to spend?
- Will the students build a full-sized or scaled-down version of the LPGC.

This extension continues after the Preliminary Design Review (PDR), with the students constructing their working prototype and presenting it at the Critical Design Review (CDR).

Big Idea: Technological devices require an extensive planning and testing phase before the final production stage.
Teacher's Note: Big ideas should be made explicit to students by writing them on the board and/or reading them aloud.

Purpose of Lesson: This lesson enables students to follow a project through to the final stage of the engineering design process.

Lesson Duration: Seven to eleven hours.

Activity Highlights

Engagement: Students list all materials needed to build their design. They need to determine what must be purchased in order to remain within their budgets. They gather all necessary materials in preparation for the build.

Exploration: Students explore the various hand and power tools available to them for the construction phase.

Explanation: The teacher explains:

- Mechanical subsystems may be required to circulate air, water, nutrients.
- How to refine a design by using prototypes and modeling to ensure quality, efficiency and productivity of the final product.
- How to evaluate the design solution using conceptual, physical and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.
- How to use the available tools safely and efficiently.

Extension: Working with their partners, students construct their prototype growth chambers.

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

Lesson 4: Overview

Lesson Duration
- Seven to eleven hours.

Standards/Benchmarks
Technology: Standards for Technological Literacy (*STL*) *(ITEA, 2000/2002)*
- Abilities to apply the design process. (ITEA/*STL* 11)
  - Refine a design by using prototypes and modeling to ensure quality, efficiency and productivity of the final product. (ITEA/*STL* 11O)
  - Evaluate the design solution using conceptual, physical and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed. (ITEA/*STL* 11P)

Science: Benchmarks for Science Literacy *(AAAS, 1993)*
- The Nature of Technology/Design and Systems (AAAS 3B)
  - In designing a device or process, thought should be given to how it will be manufactured, operated, maintained, replaced and disposed of and who will sell, operate and take care of it. The costs associated with these functions may introduce yet more constraints on the design.
  - The more parts and connections a system has, the more ways it can go wrong. Complex systems usually have components to detect, back up, bypass or compensate for minor failures.
  - To reduce the chance of system failure, performance testing is often conducted using small-scale models, computer simulations, analogous systems or just the parts of the system thought to be least reliable.

Learning Objectives
Note: For each objective below, T represents technology or ITEA/*STL* standards; M represents mathematics or NCTM standards; S represents science or AAAS standards. Standards are listed above.

Students will:
1. Refine a design by using prototypes and modeling to ensure quality, efficiency and productivity of the final product. (T 11O)
2. Evaluate the design solution using conceptual, physical and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed. (T 11P)
3. Explain that when designing a device or process, thought should be given to how it will be manufactured, operated, maintained, replaced and disposed of and who will sell, operate and take care of it. The costs associated with these functions may introduce yet more constraints on the design. (S 3B)
4. Explain that the more parts and connections a system has, the more ways it can go wrong. Complex systems usually have components to detect, back up, bypass or compensate for minor failures. (S 3B)
5. Explain that to reduce the chance of system failure, performance testing is often conducted using small-scale models, computer simulations, analogous systems or just the parts of the system thought to be least reliable. (S 3B)
6. Work safely and accurately with a variety of tools, machines and materials.
7. Actively participate in group discussions, ideation exercises and debates.

Student Assessment Tools

1. Quiz (See ***Unit Pre- and Post-Test***)

2. Optional Rubric for Group Work
   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
Participation	Seldom participated. Did very little work.	Cooperative. Did his/her part of the work. Often offered useful ideas.	Was always willing to do more. Routinely offered useful ideas.
Reliability	Did not have work done on time. Did not show up when the group met.	Group members could count on him/her.	Went beyond what was expected of him/her.
Attitude	Did not support group members. Did not share information. Had little interest in success of the group.	Supported efforts of others. Served to facilitate rather than disrupt the group work.	Listened to and shared ideas with others. Was very self directed.

3. Assessment Instrument – Prototype

Category	Below Target	At Target	Above Target
Development	Unsafe practices used in the lab. Not considerate of others around.	Worked safely in the lab. Has respect for others' work.	Worked safely in the lab. Willing to help others in the lab.
Prototype Development	Prototype was poorly made and was not representative of the technology.	Prototype was well crafted and represented the technology accurately.	Prototype was very well crafted and was very representative of the technology.
Prototype Details	Details were missing or misrepresented; did not meet the design criteria.	Many details of the technology were easily seen. Met the design criteria.	Prototype was extremely detailed and accurate. Met all design criteria and constraints.

4. Assessment Totals

Element	Criteria	Points Possible	Earned Assessment Self / Teacher
Quiz	As per above		
Group Work	As per above		
Research Analysis	As per above		

Resource Materials

Print Materials

1. Owners' manuals for machines in the technology lab that students will be allowed to use.

Required Knowledge and Skills

- Knowledge of tools and tool safety is necessary for this activity. The teacher will need to determine which tools students will be allowed to use. Iteration or the act of repeating, may be important here to ensure student safety.

Lesson 4: Modified 5-E Lesson Plan

Engagement

1. Students work with the teacher to list all materials needed to build their design. They will need to determine what must be purchased and what compromises must be made to accommodate materials already available in the lab.
2. Students gather all necessary materials in preparation for the build.

Exploration

Students explore the various hand and power tools available to them for the construction phase. *Teacher's Note*: Ensure that students are aware of proper safety rules for all equipment available.

Explanation

The students work in groups to discuss:

- Refining a design by using prototypes and modeling to ensure quality, efficiency and productivity of the final product.
- Evaluating the design solution using conceptual, physical and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed.
- The safe and efficient use of available tools.
- That the Critical Design Review (CDR) will require a presentation to the rest of the class. Further, the CDR is a technical review that ensures the project can begin system fabrication, demonstration and testing. The CDR also reviews the requirements from the Preliminary Design Review (PDR), which included performance specifications for subsystems, cost analysis and a schedule with milestones. The CDR will evaluate the final system design.
- Students build prototypes and present them to the CDR committee, describing all parts, how they function, and what parts or subsystems they work with.

Extension

1. Working in teams, students construct their prototype growth chambers.
2. Students test each subsystem during the development process and then as a part of the entire system. Subsystems may go through a series of iterations (repetitions) until all subsystems operate as a total system.
3. Students present their work to their peers at the CDR.

Enrichment

The teacher can arrange an additional CDR for the students that would include engineers, scientists and other interested individuals from the local community.

Evaluation

1. Student knowledge, skills and attitudes are assessed using selected response items.
2. Rubrics are provided for group work and prototype development.

Lesson 4: Lesson Preparation

Teacher Planning

Teachers should ensure that all students understand the safe use of all tools and equipment available. Students may have learned the safe use of tools in another course (i.e., a technology education course). If not, the teacher may have to demonstrate safe use of the tools the students will use.

Tools/Materials/Equipment

Students should have access to a laboratory-classroom with a variety of tools, equipment and materials to complete their assignment. At the discretion of the teacher, students with prior experience may use hand tools and power tools.

Potential Materials
(A number of readily available materials may be used for building the lunar plant growth chamber.)

- Plywood
- Wood glue and/or plastic cement
- Staple gun and staples
- Electric wire
- Clear plastic sheet
- Acrylic
- Screws and nails
- Plastic tubing and syringes
- Lightbulbs and fixtures
- Hinges

Classroom Safety and Conduct

1. Students use tools and equipment safely, maintaining a safety level for themselves and others in the laboratory-classroom.
2. Students demonstrate respect and courtesy for the ideas expressed by others in the class.
3. Students show respect and appreciation for the efforts of others.
4. Students wear eye protection and work safely with knives, scissors and hot glue guns.

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Appendices
Resource Documents

Design Challenge: Lunar Plant Growth Chamber

Name ____________________
Date _____________________

Unit Pre/Post-Test

The following questions are taken from each set of unit lessons. They represent the knowledge assessment component for each lesson, but may be used as a pre-assessment tool.

Lesson 1 Questions

Directions: Select the response that best answers the question or statement.

1-1. Technological problems such as this design challenge are:
- A. Seldom clearly defined.
- B. Always clearly defined.
- C. Solved by one obvious solution.
- D. Solved with little to no research.

1-2. The availability of new technology:
- A. Limits scientific research.
- B. Often sparks scientific advances.
- C. Does not affect research because it is always so expensive.
- D. Has no effect on research and development.

Directions: Provide answers to the following questions:

1-3. Most scientists do not believe that lunar colonists could grow all the food they would need. Why should they grow any food?

1-4. A growth chamber on the moon would need to be large enough for the plants that will be grown there. What mathematical formula would be used to calculate volume?

Design Challenge: Lunar Plant Growth Chamber

Name ___________________
Date ____________________

Unit Pre/Post-Test

The following questions are taken from each set of unit lessons. They represent the knowledge assessment component for each lesson, but may be used as a pre-assessment tool.

Lesson 2 Questions

Directions: Select the response that best answers the question or statement.

2-1. The requirements of a design, such as criteria, constraints and efficiency:

A. Sometimes compete with each other.
B. Have nothing to do with solving problem.
C. Are important, but do not need to be considered on this project.
D. Are always in harmony with each other.

2-2. When chemical elements are combined and recombined in living things such as plants, some energy is stored and some energy is:

A. Destroyed.
B. Dissipated into the environment as light.
C. Dissipated into the environment as heat.
D. Dissipated into the environment as moisture.

Directions: Provide answers to the following questions.

2-3. Describe two characteristics plants should have in order to be considered suitable for a lunar greenhouse.

2-4. Describe conditions on the moon that necessitate a closed, artificial environment in which to grow plants.

Design Challenge: Lunar Plant Growth Chamber

Name ________________
Date _________________

Unit Pre/Post-Test

The following questions are taken from each set of unit lessons. They represent the knowledge assessment component for each lesson, but may be used as a pre-assessment tool.

Lesson 3 Questions

Directions: Select the response that best answers the question or statement.

3-1. The design process requires continual checking, testing and refining of parts and sub-systems:

A. To ensure that all parts and sub-systems will be compatible with each other and perform as designed.
B. To test how long parts and sub-systems will last before they wear out.
C. In order to provide jobs for as many people as possible.
D. Because it is the least expensive part of the design process.

3-2. Engineering design is influenced by personal characteristics of the designer. These characteristics include:
A. Creativity and the ability to speak to large groups.
B. Resourcefulness and the ability to make friends.
C. Humor and the ability to visualize.
D. Creativity, resourcefulness, and the ability to visualize.

Directions: Provide answers to the following questions:

3-3. Evaluating a design solution can be done using conceptual, physical and mathematical models. Describe how one of these models could be used to evaluate a design solution.

3-4. List and explain two important topics that must be addressed in the Preliminary Design Review.

Design Challenge: Lunar Plant Growth Chamber

Name ________________
Date _________________

Unit Pre/Post-Test

The following questions are taken from each set of unit lessons. They represent the knowledge assessment component for each lesson, but may be used as a pre-assessment tool.

Lesson 4 Questions

Directions: Select the response that best answers the question or statement.

4-1. Prototypes and models are built:
- A. To test systems and sub-systems.
- B. To provide work for engineers.
- C. Only to check for size and shape.
- D. After a final solution has been constructed.

4-2. The purpose of periodic testing of a design solution is to:
- A. Check to see what the final design will look like.
- B. Keep quality control personnel employed.
- C. Check for proper design and note areas where improvements are needed.
- D. Ensure the proper function of individual sub-systems no matter how they affect other sub-systems.

Directions: Provide answers to the following questions:

4-3. During the design process, a number of prototypes of a design solution may be built. Describe two characteristic differences in the models from one generation to the next.

4-4. Describe two components of a Critical Design Review that differentiates it from the Preliminary Design Review.

Design Challenge: Lunar Plant Growth Chamber

Pre/Post Test Answer Key

1-1) A
1-2) B
1-3) Answers may include, but are not limited to the need for supplements to the pre-packaged meals, psychological effects of growing plants, and experimentation for future exploration beyond the moon.
1-4) Answers will vary, but should give a valid formula for volume such as surface area multiplied by height.

2-1) A
2-2) C
2-3) Answers could include any two of the following: High Growth Rates, Small Waste Percentage, Low Maintenance, High Yield of Oxygen, and Small Growing Area. Other options may be acceptable depending upon class discussions.
2-4) Should include: Lack of atmosphere, Lack of nutrients in regolith, lack of available ambient moisture and duration of daylight.

3-1) A
3-2) D
3-3) Conceptual – gives overview of requirements and requires address of design constraints, needs, and efficiency
Physical – Allows for testing of systems to evaluate design
Mathematical – allows for computer simulation of design
3-4) Answers will vary depending upon classroom discussion.

4-1) A
4-2) C
4-3) Answers will depend upon class discussion
4-4) Final design is presented and changes made are explained and justified.

STS-118 Lunar Plant Growth Chamber (LPGC) Design Challenge Brief

Context

You are a member of the engineering and life science team that wishes to study plant growth on the moon. Your team realizes that a lunar colony may not be able to produce all the food needed, but may be able to produce enough to enhance the menu brought from Earth with some fresh plants. It is your team's responsibility to select plants and design a prototype lunar plant growth chamber that could be used on the moon.

Challenge Criteria and Constraints

For this five-part challenge, you will perform the same steps as NASA engineers.

1. You must decide which plants would be best to grow in your LPGC.
    a. Decide what species would be best (this must integrate personal preferences with research).
    b. Research the requirements of each plant species in order to keep it healthy (air, water, light, nutrients, etc.)

2. You must design an LPGC that will occupy less space on a cargo spacecraft than it will on the moon to facilitate transportation from Earth.
    a. Collapsible volume will be one cubic meter.
    b. Functional volume will be two cubic meters.
    c. The prototype model will be a scale of 1:4.
    d. You must design the subsystems (air, water, light, nutrients, etc.) for your LPGC that are needed to keep your plants healthy.

3. You must present your model to the class in a presentation called a Preliminary Design Review (PDR).

4. At the discretion of the teacher, you will make modifications to your design that were discussed at the PDR, and you will build a functional (working) prototype. (Boxes and various pieces of hardware may be used to represent pumps, sensors, etc. which may be too difficult or expensive to obtain.)

5. You must present this final model to the class in a presentation called the Critical Design Review (CDR).

PDR Date: ____________________ CDR Date: ____________________

Design, Build and Evaluate

Procedure:

1. Your team will research different plant species to determine whether they are appropriate crops for a lunar plant growth chamber.

2. You will also participate in a number of briefings (lessons) by a consultant (your teacher).

3. You will design a prototype of your growth chamber using simple materials.

4. You will present your designs to your classmates in a short presentation called a Preliminary Design Review (PDR).

5. Your team will build a functional prototype that incorporates suggestions for improvement that resulted from the PDR.

6. You will present your improved prototype designs to your classmates in a short presentation called a Critical Design Review (CDR). During the CDR, you will explain the changes and modifications you made to your model.

Materials:

Computer with Internet access, pencil, paper, color markers, worksheets, cardboard, foam core board, hot glue, tape and other materials students might bring from home. Also, tools and materials appropriate for modeling, such as wood, acrylic, metal, cardboard, glue, mechanical fasteners, electrical components, plastic tubing, spray paint, sensors, pumps, calculator-based labs or mockup boxes representing any of these last items, etc.

Evaluation:

Rubrics are used for group work, research, analysis, presentation and model/prototype.

PDR Date: ____________________

Design and Evaluate

Procedure:

1. Your team will research different plant species to determine whether they are appropriate crops for a lunar plant growth chamber.

2. You will also participate in a number of briefings (lessons) by a consultant (your teacher).

3. You will design a prototype of your growth chamber using simple materials.

4. You will present your designs to your classmates in a short presentation called a Preliminary Design Review (PDR).

Materials:

Computer with Internet access, pencil, paper, color markers, worksheets, cardboard, foam core board, hot glue, tape and other materials students might bring from home.

Evaluation:

Rubrics will be used for group work, research, analysis and presentation.

. Name: ____________________
Name: ____________________
Date: ______________________

Growth Chamber Plant List

Plant Name	Positive Characteristics	Negative Characteristics
______________	______________________	______________________
	______________________	______________________
______________	______________________	______________________
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	______________________	______________________

Name: ______________________
Name: ______________________
Date: ________________________

Top Five Plant List Worksheet

Plant Name

Research and list all requirements your plants need to stay healthy. Include nutrients, temperature, lighting, etc.

STS-118 Lunar Plant Growth Chamber (LPGC) Engineering Design Process

Name ________________

Date __________________

The engineering design process involves a series of steps that lead to the development of a new product or system. The process of design often takes place within a team of two or more people. Follow instructions for each of the steps below.

Identify the Problem – Re-state the LPGC challenge problem in your own words.

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Identify Criteria and Constraints – Identify specifically what the LPGC solution should be able to do and how well it should do it. As you work, you may identify additional criteria and constraints that were not obvious at first. Be sure to list them as well.

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Brainstorm Possible Solutions – Sketch ideas as the team discusses ways to solve the problem. Include labels and arrows to identify parts and how they might move. These drawings should be quick rough drafts. Elect one team member to write these ideas on the board (or large chart) so everyone can see the possibilities. (Draw individual part or subsystem sketches on separate sheets and attach to larger one.)

Generate Ideas – Develop two or three of the ideas more thoroughly. Start new drawings that show multiple views (orthographic) and three-dimensional depictions (for example, isometric). See examples of these views in the Sketching and Drawing handout. Draw neatly using rulers to draw straight lines and make parts proportional. Label parts and measurements clearly. (Work on separate sheets and attach to this one.)

Explore Possibilities – Share and discuss ideas with your team members. Record the pros and cons of each design idea directly on the paper next to your drawings.

Select an Approach – As a team, identify the design that appears to best solve the problem. Write a statement that describes why that solution was chosen. This statement should include references to the criteria and constraints identified on the previous page.

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Make a Model or Prototype – Construct a model (full-sized or scale-sized – your teacher will direct you) based on the drawings. Use inexpensive and easy-to-work-with modeling materials (cardboard, foam core board, tape, etc.).

Refine the Design – Examine and evaluate the prototypes or designs based on the criteria and constraints. Enlist other individuals or groups to review the solution and help identify changes that need to be made. List any problems found (based on criteria and constraints) and possible corrections. This step may require the team to loop back to a previous step to revisit other ideas and possible solutions.

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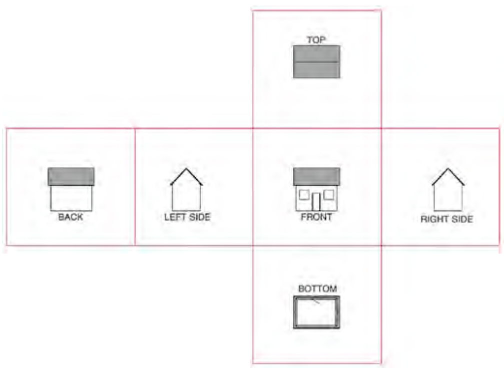
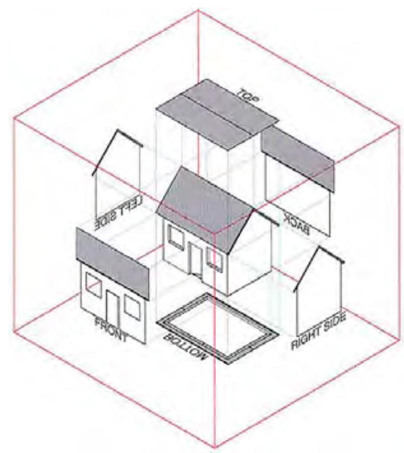
Sketching and Drawing

Sketching is a quick way to record ideas about shape and relative sizes of parts in a design. It is an ideal way to record thoughts while brainstorming possible solutions. Sketches should include some labels and notes about possible sizes of parts. Sketching on graph paper is recommended.

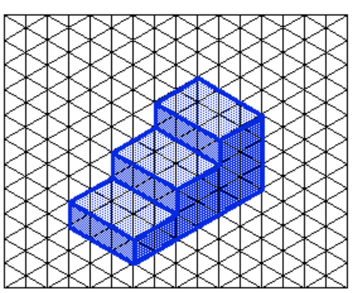
Orthographic Projection is a way of drawing different views of the same object. Usually a front, side and plan view is drawn so that a person looking at the drawing can see all the important sides. These are useful when a design has been developed to a stage whereby it is almost ready to manufacture. One view cannot provide all of the information needed to describe the object.



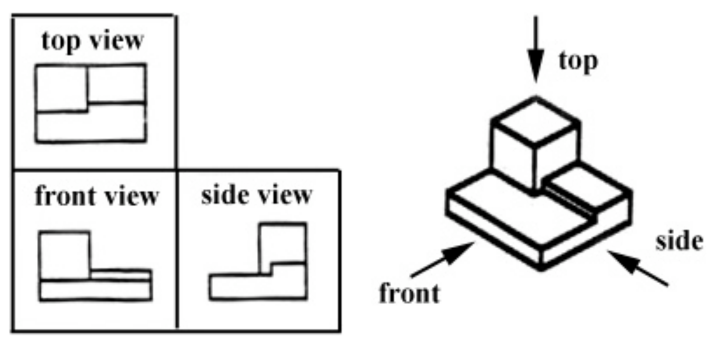


From http://www2.arts.ubc.ca/TheatreDesign/crslib/drft_1/orthint.htm

Isometric Drawing is a form of 3-D drawing in which there are three types of lines: vertical lines, 30° lines to the right and 30° lines to the left. Isometric graph paper makes it easy to draw neat, accurate images of design ideas. See the next page for a sample.

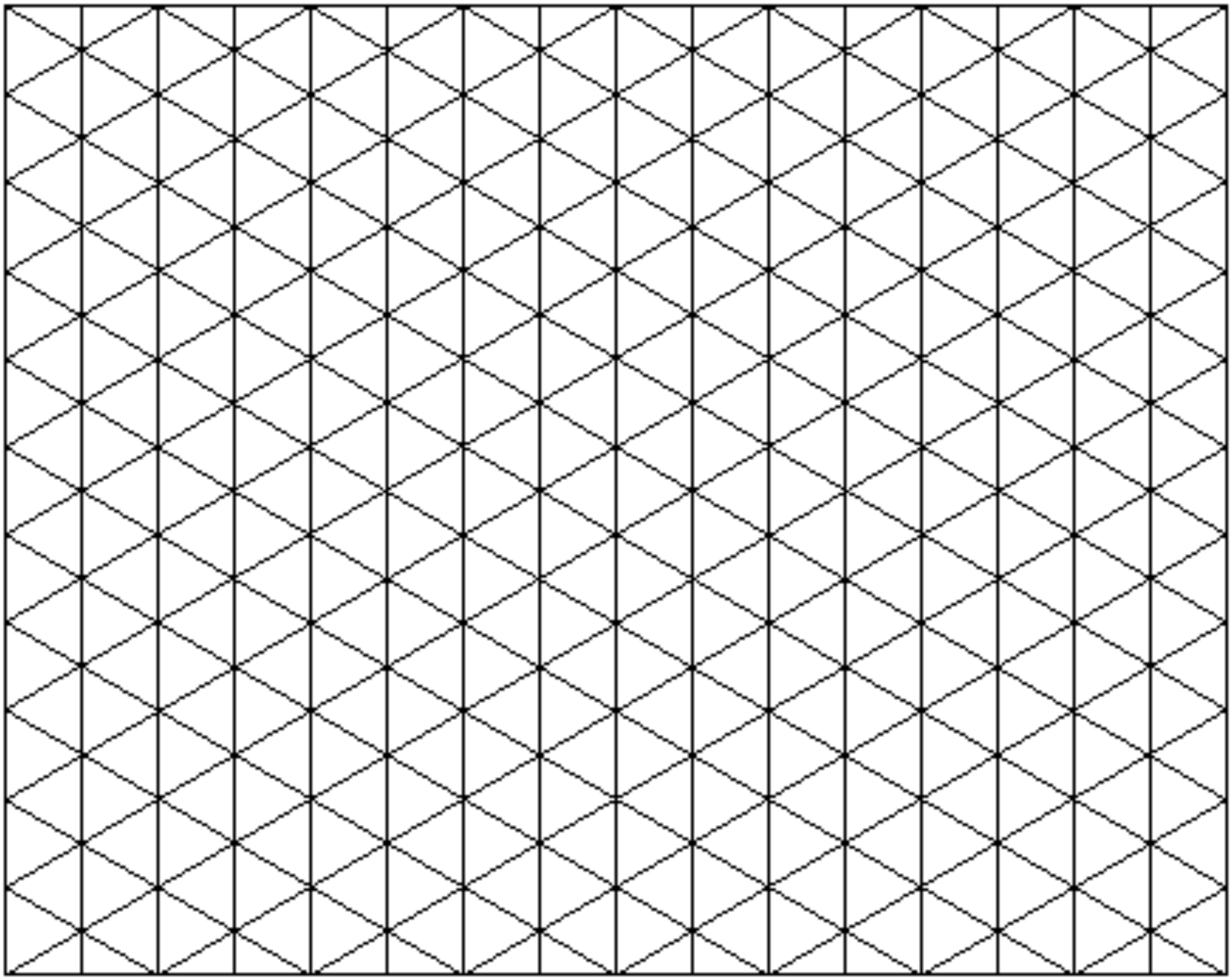


3 stairs

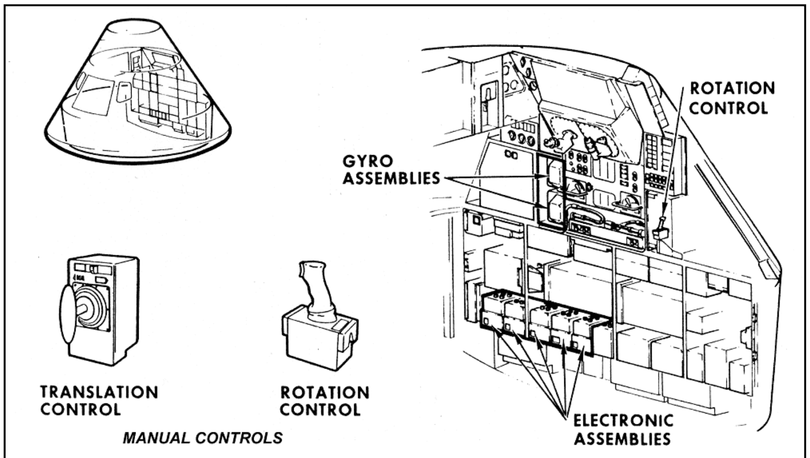


http://mathforum.org/workshops/sum98/participants/sanders/IsomExamples.html

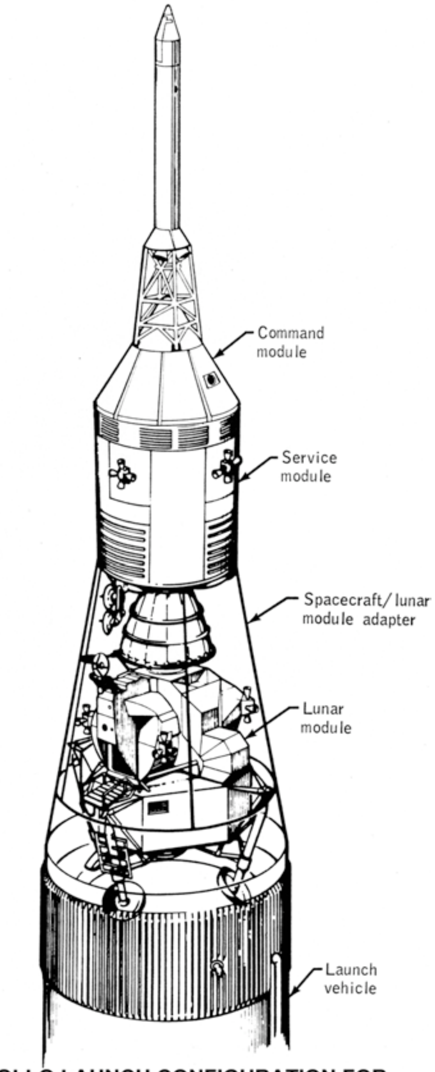
http://pergatory.mit.edu/2.007/Resources/drawings/images/fig_02.jpg



These are some of the many diagrams that may be shown to students as examples of how information can be shared graphically.

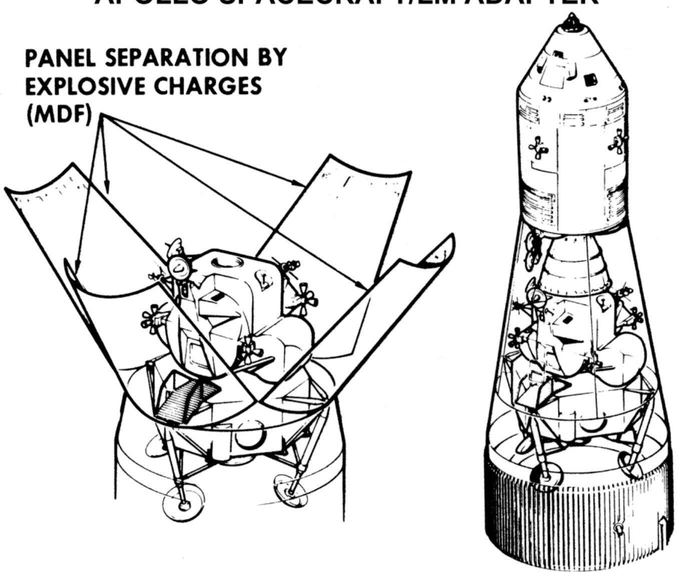


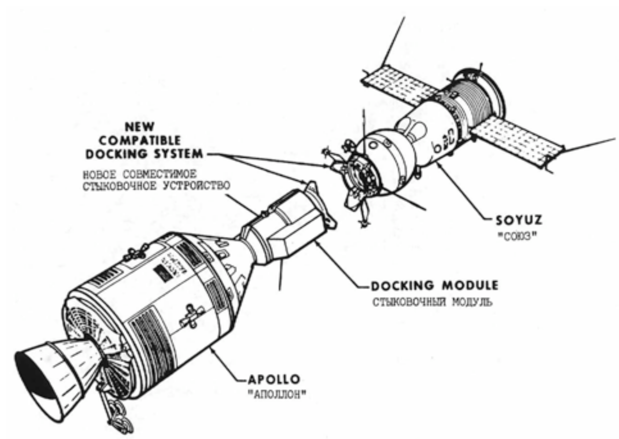
COMMAND MODULE STABILIZATION & CONTROL SYSTEM



APOLLO LAUNCH CONFIGURATION FOR LUNAR LANDING MISSION

APOLLO SPACECRAFT/LM ADAPTER





- Apollo-Soyuz Rendezvous and Docking Test project

ЭКСПЕРИМЕНТАЛЬНЫЙ ПРОЕКТ ВСТРЕЧИ И СТЫКОВКИ КОСМИЧЕСКИХ КОРАБЛЕЙ

Teacher's Note: Source: http://history.nasa.gov/diagrams/apollo.html

Standards for Technological Literacy Program Responsibility Matrix

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	Course Total	K-2	3-5	Exploring Technology	Invention & Innovation	Systems	Foundations	Impacts	Issues	Technological Design	Advanced Design Applications	Advanced Technological Applications	Engineering Design
		172	232	212	147	166	202	154	97	182	236	209	187
The Nature of Technology													
STL-1	**Understanding the characteristics and scope of technology**	8	12	12	16	7	10	8	12	10	9	10	11
A	The natural world and human-made world are different.	4											
B	All people use tools and techniques to help them do things.	4											
C	Things that are found in nature differ from things that are human-made in how they are produced and used.		4										
D	Tools, materials, and skills are used to make things and carry out tasks.		4										
E	Creative thinking and economic and cultural influences shape technological development.		4										
F	New products and systems can be developed to solve problems or to help do things that could not be done without the help of technology.			4	4	4							
G	The development of technology is a human activity and is the result of individual or collective needs and the ability to be creative.			3	4								
H	Technology is closely linked to creativity, which has resulted in innovation.			3	4								
I	Corporations can often create demand for a product by bringing it onto the market and advertising it.			2	4	3							
J	The nature and development of technological knowledge and processes are functions of the setting.						4	2	2	4	3	4	4
K	The rate of technological development and diffusion is increasing rapidly.						2	4	3				
L	Inventions and innovations are the results of specific, goal-oriented research.						2	2	3	3	4	4	4
M	Most development of technologies these days is driven by the profit motive and the market.						2		4	3	2	2	3

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	Course Total	172	232	212	147	166	202	154	97	182	236	209	187
	The Nature of Technology												
STL-2	**Understanding the core concepts of technology**	20	28	21	10	33	114	0	0	33	33	33	36
A	Some systems are found in nature, and some are made by humans.	4											
B	Systems have parts or components that work together to accomplish a goal.	4											
C	Tools are simple objects that help humans complete tasks.	4											
D	Different materials are used in making things.	4											
E	People plan in order to get things done.	4											
F	A subsystem is a system that operates as a part of another system.		4										
G	When parts of a system are missing, it may not work as planned.		4										
H	Resources are the things needed to get a job done, such as tools and machines, materials, information, energy, people, capital, and time.		4										
I	Tools are used to design, make, use, and assess technology.		4										
J	Materials have many different properties.		4										
K	Tools and machines extend human capabilities, such as holding, lifting, carrying, fastening, separating, and computing.		4										
L	Materials have many different properties.		4										
M	Technological systems include input, processes, output, and, at times, feedback.			4		3							
N	Systems thinking involves considering how every part relates to others			4		3							
O	An open-loop system has no feedback path and requires human intervention, while a closed-loop system uses feedback.					4							
P	Technological systems can be connected to one another.			3		4							
Q	Malfunctions of any part of a system may affect the function and quality of the system.				3	4							
R	Requirements are the parameters placed on the development of a product or system.				3	4							
S	Trade-off is a decision process recognizing the need for careful compromises among competing factors.				4								
T	Trade-off is a decision process recognizing the need for careful compromises among competing factors.			4		3							
U	Different technologies involve different sets of processes.			3		4							

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	Course Total	172	232	212	147	166	202	154	97	182	236	209	187
STL-2	**Understanding the core concepts of technology (continued)**	20	28	21	10	33	14	0	0	33	33	33	36
V	Controls are mechanisms or particular steps that people perform using information about the system that causes systems to change.			3		4							
W	Systems thinking applies logic and creativity with appropriate compromises in complex real-life problems.									4	4	4	4
X	Systems, which are the building blocks of technology, are embedded within larger technological, social, and environmental systems.						4				3	4	
Y	The stability of a technological system is influenced by all of the components in the system, especially those in the feedback loop.						3			4	4	3	4
Z	Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste.						3			4	2	2	4
AA	Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development.									4	4	4	4
BB	Optimization is an ongoing process or methodology of designing or making a product and is dependent on criteria and constraints.									3	4	3	4
CC	New technologies create new processes.						4			4	3	4	4
DD	Quality control is a planned process to ensure that a product, service, or system meets established criteria.									3	3	2	4
EE	Management is the process of planning, organizing, and controlling work.									3	2	3	4
FF	Complex systems have many layers of controls and feedback loops to provide information.									4	4	4	4

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STL-3	**Understanding the relationships among technologies and connections with other fields of study**	**4**	**8**	**6**	**5**	**12**	**11**	**5**	**7**	**12**	**10**	**10**	**12**
A	The study of technology uses many of the same ideas and skills as other subjects.	4											
B	Technologies are often combined.		4										
C	Various relationships exist between technology and other fields of study.		4										
D	Technological systems often interact with one another.			3	2	4							
E	A product, system, or environment developed for one setting may be applied to another setting.				3	4							
F	Knowledge gained from other fields of study has a direct effect on the development of technological products and systems.			3		4							
G	Technology transfer occurs when a new user applies an existing innovation developed for one purpose in a different function.						3	2		4	4	3	4
H	Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among						3			4	3	4	4
I	Technological ideas are sometimes protected through the process of patenting.						2		3	4			4
J	Technological progress promotes the advancement of science and mathematics.						3	3	4		3	3	
Technology and Society													
STL-4	**Understanding the cultural, social, economic and political effects of technology**	**4**	**8**	**14**	**11**	**3**	**2**	**13**	**10**	**6**	**7**	**8**	**4**
A	The use of tools and machines can be helpful or harmful.	4											
B	When using technology, results can be good or bad.		4										
C	The use of technology can have unintended consequences.		4										
D	The use of technology affects humans in various ways, including their safety, comfort, choices, and attitudes about technology's development and use.			4									
E	Technology, by itself, is neither good nor bad, but decisions about the use of products and systems can result in desirable or undesirable consequences.			4	3	3							
F	The development and use of technology poses ethical issues.			3	4								
G	Economic, political, and cultural issues are influenced by the development and use of technology.			3	4								
H	Changes caused by the use of technology can range from gradual to rapid and from subtle to obvious.							4		2	3	4	
I	Making decisions about the use of technology involves weighing the trade-offs between the positive and negative effects.						2	3	4				
J	Ethical considerations are important in the development, selection, and use of technologies.							3	2	4	4	4	4
I	The transfer of a technology from one society to another can cause cultural, social, economic, and political changes affecting both societies to varying degrees.							3	4				

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		172	232	212	147	166	202	154	97	182	236	209	187
STL-5	**Understanding the effects of technology on the environment**	**4**	**8**	**8**	**6**	**9**	**3**	**18**	**6**	**11**	**13**	**13**	**11**
A	Some materials can be reused and/or recycled.	4											
B	Waste must be appropriately recycled or disposed of to prevent unnecessary harm to the environment.		4										
C	The use of technology affects the environment in good and bad ways.		4										
D	The management of waste produced by technological systems is an important societal issue.			4		3							
E	Technologies can be used to repair damage caused by natural disasters and to break down waste from the use of various products and systems.				3	4							
F	Decisions to develop and use technologies often put environmental and economic concerns in direct competition with one another.			4	3	2							
G	Humans can devise technologies to conserve water, soil, and energy through such techniques as reusing, reducing and recycling.								4	3	2	2	3
H	When new technologies are developed to reduce the use of resources, considerations of trade-offs are important.							3		4	2	3	4
I	With the aid of technology, various aspects of the environment can be monitored to provide information for decisionmak-ing.							4			2		
J	The alignment of technological processes with natural processes maximizes performance and reduces negative impacts on the environment.							4				2	
K	Humans devise technologies to reduce the negative consequences of other technologies. 3 4 3 3 4							3		4	3	3	4
L	Decisions regarding the implementation of technologies involve the weighing of trade-offs between predicted positive and negative effects on the environment.						3	4	2		4	3	
STL-6	**Understanding the role of society in the development and use of technology**	**4**	**8**	**13**	**12**	**2**	**4**	**10**	**2**	**4**	**3**	**3**	**4**
A	Products are made to meet individual needs and wants.	4											
B	Because people's needs and wants change, new technologies are developed, and old ones are improved to meet those changes.		4										
C	Individual, family, community, and economic concerns may expand or limit the development of technologies.		4										
D	Throughout history, new technologies have resulted from the demands, values, and interests of individuals, businesses, industries, and societies.			4									
E	The use of inventions and innovations has led to changes in society and the creation of new needs and wants.			3	4								
F	Social and cultural priorities and values are reflected in technological devices.			3	4								
G	Meeting societal expectations is the driving force behind the acceptance and use of products and systems.			3	4	2							
H	Different cultures develop their own technologies to satisfy their individual and shared needs, wants, and values.							4					
I	The decision whether to develop a technology is influenced by societal opinions and demands, in addition to corporate cultures.							3	2	4			4
J	A number of different factors, such as advertising, the strength of the economy, the goals of a company, and the latest fads contribute to shaping the design of and demand for various technologies.						4	3			3	3	

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	The Nature of Technology												
	STL-7 Understanding the influence of technology on history	4	4	6	12	4	28	22	9	0	3	3	0
A	The way people live and work has changed throughout history because of technology.	4											
B	People have made tools to provide food, to make clothing, and to protect themselves.		4										
C	Many inventions and innovations have evolved by using slow and methodical processes of tests and refinements.			3	4								
D	The specialization of function has been at the heart of many technological improvements.			3	4								
E	The design and construction of structures for service or convenience have evolved from the development of techniques for measurement, controlling systems, and the understanding of spatial relationships.					4							
F	In the past, an invention or innovation was not usually developed with the knowledge of science.				4								
G	Most technological development has been evolutionary, the result of a series of refinements to a basic invention..							4					
H	The evolution of civilization has been directly affected by, and has in turn affected, the development and use of tools and materials.								3	4			
I	Throughout history, technology has been a powerful force in reshaping the social, cultural, political, and economic landscape.								4	3			
J	Early in the history of technology, the development of many tools and machines was based not on scientific knowledge but on technological know-how.							4					
K	The Iron Age was defined by the use of iron and steel as the primary materials for tools.							4	3				
L	The Middle Ages saw the development of many technological devices that produced long-lasting effects on technology and society							4	3				
M	The Renaissance, a time of rebirth of the arts and humanities, was also an important development in the history of technology.							4	3				
N	The Industrial Revolution saw the development of continuous manufacturing, sophisticated transportation and communication systems, advanced construction practices, and improved education and leisure time.							4	3				
O	The Information Age places emphasis on the processing and exchange of information.							4	3	2		3	3

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		K-2	3-5	Exploring Technology	Invention & Innovation	Systems	Foundations	Impacts	Issues	Technological Design	Advanced Design Applications	Advanced Technological Applications	Engineering Design
	Course Total	172	232	212	147	166	202	154	97	182	236	209	187
Design													
STL-8	**Understanding the attributes of design**	8	8	11	10	3	13	2	0	15	16	15	15
A	Everyone can design solutions to a problem.	4											
B	Design is a creative process.	4											
C	The design process is a purposeful method of planning practical solutions to problems.		4										
D	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.		4										
E	Design is a creative planning process that leads to useful products and systems.			3	4	3							
F	There is no perfect design.			4	3								
G	Requirements for a design are made up of criteria and constraints.			4	3								
H	The design process includes defining a problem, brainstorming, researching and generating ideas, identifying criteria and specifying constraints, exploring possibilities, selecting an approach, developing a design proposal, making a model or prototype.						4			3	4	4	3
I	Design problems are seldom presented in a clearly defined form.						3			4	4	3	4
J	The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved.						3			4	4	4	4
K	Requirements of a design, such as criteria, constraints, and efficiency, sometimes compete with each other.						3	2		4	4	4	4

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STL-9	**Understanding engineering design**	8	12	11	10	0	13	2	0	14	10	10	15
A	The engineering design process includes identifying a problem, looking for ideas, developing solutions, and sharing solutions with others.	4											
B	Expressing ideas to others verbally and through sketches and models is an important part of the design process.	4											
C	The engineering design process involves defining a problem, generating ideas, selecting a solution, testing the solution(s), making the item, evaluating it, and presenting the results.		4										
D	When designing an object, it is important to be creative and consider all ideas.		4										
E	Models are used to communicate and test design ideas and processes.		4										
F	Design involves a set of steps, which can be performed in different sequences and repeated as needed.			4	3								
G	Brainstorming is a group problem-solving design process in which each person in the group presents his or her ideas in an open forum.			3	4								
H	Modeling, testing, evaluating, and modifying are used to transform ideas into practical solutions.			4	3								
I	Established design principles are used to evaluate existing designs, to collect data, and to guide the design process.						4			3	4	3	3
J	Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly.						3			4	3	3	4
K	A prototype is a working model used to test a design concept by making actual observations and necessary adjustments.						3			4	3	4	4
L	The process of engineering design takes into account a number of factors.						3	2		3			4

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		172	232	212	147	166	202	154	97	182	236	209	187
STL-10	**Understanding the role of troubleshooting, R&D, etc. in problem-solving**	8	12	9	10	6	4	7	11	3	14	14	3
A	Asking questions and making observations helps a person to figure out how things work. .	4											
B	All products and systems are subject to failure. Many products and systems, however, can be fixed.	4											
C	Troubleshooting is a way of finding out why something does not work so that it can be fixed.		4										
D	Invention and innovation are creative ways to turn ideas into real things.		4										
E	The process of experimentation, which is common in science, can also be used to solve technological problems.		4										
F	Troubleshooting is a problem-solving method used to identify the cause of a malfunction in a technological system.			3	2	4							
G	Invention is a process of turning ideas and imagination into devices and systems. Innovation is the process of modifying an existing product or system to improve it.			3	4	2							
H	Some technological problems are best solved through experimentation.			3	4								
I	Research and development is a specific problem-solving approach that is used intensively in business and industry to prepare devices and systems for the marketplace.						4			3	3	3	3
J	Technological problems must be researched before they can be solved.							4	3		4	4	
K	Not all problems are technological, and not every problem can be solved using technology.								4		4	3	
L	Many technological problems require a multidisciplinary approach.							3	4		3	4	

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	Course Total	172	232	212	147	166	202	154	97	182	236	209	187
	Abilities for a Technological World												
STL-11	**Abilities to apply the design process**	12	16	10	19	3	18	3	4	16	18	18	17
A	Brainstorm people's needs and wants and pick some problems that can be solved through the design process.	4											
B	Build or construct an object using the design process.	4											
C	Investigate how things are made and how they can be improved.	4											
D	Identify and collect information about everyday problems that can be solved by technology, and generate ideas and requirements for solving a problem.		4										
E	The process of designing involves presenting some possible solutions in visual form and then selecting the best solution(s) from many.		4										
F	Test and evaluate the solutions for the design problem.		4										
G	Improve the design solutions.		4										
H	Apply a design process to solve problems in and beyond the laboratory-classroom.			3	4								
I	Specify criteria and constraints for the design.			3	4								
J	Make two-dimensional and three-dimensional representations of the designed solution.				4								
K	Test and evaluate the design in relation to pre-established requirements, such as criteria and constraints, and refine as needed.				4								
L	Make a product or system and document the solution.			4	3	3							
M	Identify the design problem to solve and decide whether or not to address it.							3	4				
N	Identify criteria and constraints and determine how these will affect the design process.						4			3	4	3	3
O	Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product.						4			3	4	4	3
P	Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design						3			3	3	4	4
Q	Develop and produce a product or system using a design process.						3			4	4	4	4
R	Evaluate final solutions and communicate observation, processes, and results of the entire design process, using verbal, graphic, quantitative, virtual, and written means, in addition to three-dimensional models.						4			3	3	3	3

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STL-12	**Abilities to use and maintain technological products and systems**	12	16	8	3	13	20	0	0	0	11	11	0
A	Discover how things work.	4											
B	Use hand tools correctly and safely and be able to name them correctly.	4											
C	Recognize and use everyday symbols.	4											
D	Follow step-by-step directions to assemble a product.		4										
E	Select and safely use tools, products, and systems for specific tasks.		4										
F	Use computers to access and organize information.		4										
G	Use common symbols, such as numbers and words, to communicate key ideas.		4										
H	Use information provided in manuals, protocols, or by experienced people to see and understand how things work.			4		3							
I	Use tools, materials, and machines safely to diagnose, adjust, and repair systems.					4							
J	Use computers and calculators in various applications.			4	3	2							
K	Operate and maintain systems in order to achieve a given purpose.					4							
L	Document processes and procedures and communicate them to different audiences using appropriate oral and written techniques.						4				3	3	
M	Diagnose a system that is malfunctioning and use tools, materials, machines, and knowledge to repair it.						4				4	4	
N	Troubleshoot, analyze, and maintain systems to ensure safe and proper function and precision.						4						
O	Operate systems so that they function in the way they were designed.						4						
P	Use computers and calculators to access, retrieve, organize, process, maintain, interpret, and evaluate data and information in order to communicate.						4				4	4	

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	STL-13 Abilities to assess the impact of products and systems	8	12	9	3	16	4	15	11	1	9	9	1
A	Collect information about everyday products and systems by asking questions.	4											
B	Determine if the human use of a product or system creates positive or negative results.	4											
C	Compare, contrast, and classify collected information in order to identify patterns.		4										
D	Investigate and assess the influence of a specific technology on the individual, family, community, and environment.		4										
E	Examine the trade-offs of using a product or system and decide when it could be used.		4										
F	Design and use instruments to gather data.			3		4							
G	Use data collected to analyze and interpret trends in order to identify the positive or negative effects of a technology.				3								
H	Identify trends and monitor potential consequences of technological development.			3		4							
I	Interpret and evaluate the accuracy of the information obtained and determine if it is useful.			3		4							
J	Collect information and evaluate its quality.						4	3	2	1	2	2	1
K	Synthesize data, analyze trends, and draw conclusions regarding the effect of technology on the individual, society, and environment.							4	3		3	3	
L	Use assessment techniques, such as trend analysis and experimentation to make decisions about the future development of technology.							4	3		4		
M	Design forecasting techniques to evaluate the results of altering natural systems.							4	3			4	

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	Course Total	172	232	212	147	166	202	154	97	182	236	209	187
	The Designed World												
STL-14	**Understanding of and abilities to select and use medical technologies**	12	12	14	0	8	4	4	4	0	0	12	0
A	Vaccinations protect people from getting certain diseases.	4											
B	Medicine helps people who are sick to get better.	4											
C	There are many products designed specifically to help people take care of themselves.	4											
D	Vaccines are designed to prevent diseases from developing and spreading; medicines are designed to relieve symptoms and stop diseases from developing.		4										
E	Technological advances have made it possible to create new devices, to repair or replace certain parts of the body, and to provide a means for mobility.		4										
F	Many tools and devices have been designed to help provide clues about health and to provide a safe environment.		4										
G	Advances and innovations in medical technologies are used to improve healthcare.			4									
H	Sanitation processes used in the disposal of medical products help to protect people from harmful organisms and disease, and shape the ethics of medical safety.			4									
I	The vaccines developed for use in immunization require specialized technologies to support environments in which a sufficient amount of vaccines are produced.			3		4							
J	Genetic engineering involves modifying the structure of DNA to produce novel genetic make-ups.			3		4							
K	Medical technologies include prevention and rehabilitation, vaccines and pharmaceuticals, medical and surgical procedures, genetic engineering, and the systems within which health is protected and maintained.							4				4	
L	Telemedicine reflects the convergence of technological advances in a number of fields, including medicine, telecommunications, virtual presence, computer engineering, informatics, artificial intelligence, robotics, materials science, and perceptual psycho						4					4	
M	The sciences of biochemistry and molecular biology have made it possible to manipulate the genetic information found in living creatures.								4			4	

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	STL-15 Understanding of and abilities to select and use agricultural and biotechnologies	8	12	12	4	4	4	4	7	4	0	16	4
A	The use of technologies in agriculture makes it possible for food to be available year round and to conserve resources.	4											
B	There are many different tools necessary to control and make up the parts of an ecosystem.	4											
C	Artificial ecosystems are human-made environments that are designed to function as a unit and are comprised of humans, plants, and animals.		4										
D	Most agricultural waste can be recycled.		4										
E	Many processes used in agriculture require different procedures, products, or systems.		4										
F	Technological advances in agriculture directly affect the time and number of people required to produce food for a large population.			4									
G	A wide range of specialized equipment and practices is used to improve the production of food, fiber, fuel, and other useful products and in the care of animals.					4							
H	Biotechnology applies the principles of biology to create commercial products or processes.				4								
I	Artificial ecosystems are human-made complexes that replicate some aspects of the natural environment.			4									
J	The development of refrigeration, freezing, dehydration, preservation, and irradiation provide long-term storage of food and reduce the health risks caused by tainted food.			4									
K	Agriculture includes a combination of businesses that use a wide array of products and systems to produce, process, and distribute food, fiber, fuel, chemical, and other useful products.						4					4	
L	Biotechnology has applications in such areas as agriculture, pharmaceuticals, food and beverages, medicine, energy, the environment, and genetic engineering.							4	3			4	
M	Conservation is the process of controlling soil erosion, reducing sediment in waterways, conserving water, and improving water quality.								4			4	
N	The engineering design and management of agricultural systems require knowledge of artificial ecosystems and the effects of technological development on flora and fauna.									4		4	4

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		K-2	3-5	Exploring Technology	Invention & Innovation	Systems	Foundations	Impacts	Issues	Technological Design	Advanced Design Applications	Advanced Technological Applications	Engineering Design
STL-16	**Understanding of and abilities to select and use energy and power technologies**	**8**	**8**	**12**	**0**	**8**	**12**	**6**	**3**	**17**	**20**	**0**	**17**
A	Energy comes in many forms.	4											
B	Energy should not be wasted.	4											
C	Energy comes in different forms.		4										
D	Tools, machines, products, and systems use energy in order to do work.		4										
E	Energy is the capacity to do work.			4									
F	Energy can be used to do work, using many processes.					4							
G	Power is the rate at which energy is converted from one form to another or transferred from one place to another, or the rate at which work is done.			4									
H	Power systems are used to drive and provide propulsion to other technological products and systems.					4							
I	Much of the energy used in our environment is not used efficiently.			4									
J	Energy cannot be created nor destroyed; however, it can be converted from one form to another.						4			3	4		3
K	Energy can be grouped into major forms: thermal, radiant, electrical, mechanical, chemical, nuclear, and others.						4			3	4		3
L	It is impossible to build an engine to perform work that does not exhaust thermal energy to the surroundings.							4		3	4		3
M	Energy resources can be renewable or nonrenewable.						1	2	3	4	4		4
N	Power systems must have a source of energy, a process, and loads.						3			4	4		4

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STL-17	**Understanding of and abilities to select and use information and communication technologies**	**12**	**16**	**13**	**4**	**8**	**16**	**8**	**8**	**7**	**0**	**24**	**7**
A	Information is data that has been organized.	4											
B	Technology enables people to communicate by sending and receiving information over a distance.	4											
C	People use symbols when they communicate by technology.	4											
D	The processing of information through the use of technology can be used to help humans make decisions and solve problems.		4										
E	Information can be acquired and sent through a variety of technological sources, including print and electronic media.		4										
F	Communication technology is the transfer of messages among people and/or machines over distances through the use of technology.		4										
G	Letters, characters, icons, and signs are symbols that represent ideas, quantities, elements, and operations.		4										
H	Information and communication systems allow information to be transferred from human to human, human to machine, and machine to human.			3		4							
I	Communication systems are made up of a source, encoder, transmitter, receiver, decoder, and destination.			3		4							
J	The design of a message is influenced by such factors as the intended audience, medium, purpose, and nature of the message.			4									
K	The use of symbols, measurements, and drawings promotes clear communication by providing a common language to express ideas.			3	4								
L	Information and communication technologies include the inputs, processes, and outputs associated with sending and receiving information.						4					4	
M	Information and communication systems allow information to be transferred from human to human, human to machine, machine to human, and machine to machine.						4					4	
N	Information and communication systems can be used to inform, persuade, entertain, control, manage, and educate.						1	4	4			4	
O	Communication systems are made up of source, encoder, transmitter, receiver, decoder, storage, retrieval, and destination.						4					4	
P	There are many ways to communicate information, such as graphic and electronic means.							4	4	4		4	3
Q	Technological knowledge and processes are communicated using symbols, measurement, conventions, icons, graphic images, and languages that incorporate a variety of visual, auditory, and tactile stimuli.						3			4		4	4

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	STL-18 Understanding of and abilities to select and use transportation technologies	12	8	4	4	11	4	8	0	4	16	0	4
A	A transportation system has many parts that work together to help people travel.	4											
B	Vehicles move people or goods from one place to another in water, air, or space and on land.	4											
C	Transportation vehicles need to be cared for to prolong their use.	4											
D	The use of transportation allows people and goods to be moved from place to place.		4										
E	A transportation system may lose efficiency or fail if one part is missing or malfunctioning or if a subsystem is not working.		4										
F	Transporting people and goods involves a combination of individuals and vehicles.			4		3							
G	Transportation vehicles are made up of subsystems, such as structural, propulsion, suspension, guidance, control, and support, that must function together for a system to work effectively.					4							
H	Governmental regulations often influence the design and operation of transportation systems.				4								
I	Processes, such as receiving, holding, storing, loading, moving, unloading, delivering, evaluating, marketing, managing, communicating, and using conventions are necessary for the entire transportation system to operate efficiently.					4							
J	Transportation plays a vital role in the operation of other technologies, such as manufacturing, construction, communication, health and safety, and agriculture.						4				4		
K	Intermodalism is the use of different modes of transportation, such as highways, railways, and waterways as part of an interconnected system that can move people and goods easily from one mode to another.							4			4		
L	Transportation services and methods have led to a population that is regularly on the move.							4			4		
M	The design of intelligent and non-intelligent transportation systems depends on many processes and innovative techniques									4	4		4

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	STL-19 Understanding of and abilities to select and use manufacturing technologies	**8**	**12**	**12**	**8**	**4**	**10**	**15**	**3**	**14**	**24**	**0**	**15**
A	Manufacturing systems produce products in quantity.	4											
B	Manufactured products are designed.	4											
C	Processing systems convert natural materials into products.		4										
D	Manufacturing processes include designing products, gathering resources, and using tools to separate, form, and combine materials in order to produce products.		4										
E	Manufacturing enterprises exist because of a consumption of goods.		4										
F	Manufacturing systems use mechanical processes that change the form of materials through the processes of separating, forming, combining, and conditioning them.			4									
G	Manufactured goods may be classified as durable and non-durable.			4									
H	The manufacturing process includes the designing, development, making, and servicing of products and systems.					4							
I	Chemical technologies are used to modify or alter chemical substances.				4								
J	Materials must first be located before they can be extracted from the earth through such processes as harvesting, drilling, and mining.			4									
K	Marketing a product involves informing the public about it well as assisting in selling and distributing it.				4								
L	Servicing keeps products in good operating condition.							4					
M	Materials have different qualities and may be classified as natural, synthetic, or mixed.						4	3		3	4		3
N	Durable goods are designed to operate for a long period of time, while non-durable goods are designed to operate for a short period of time.									4	4		4
O	Manufacturing systems may be classified into types, such as customized production, batch production, and continuous production.						3			3	4		4
P	The interchangeability of parts increases the effectiveness of manufacturing processes.						3			4	4		4
Q	Chemical technologies provide a means for humans to alter or modify materials and to produce chemical products.							4			4		
R	Marketing involves establishing a product's identity, conducting research on its potential, advertising it, distributing it, and selling it.							4	3		4		

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		172	232	212	147	166	202	154	97	182	236	209	187
STL-20	**Understanding of and abilities to select and use construction technologies**	**8**	**12**	**7**	**0**	**12**	**8**	**4**	**0**	**11**	**20**	**0**	**11**
A	People live, work, and go to school in buildings, which are of different types: houses, apartments, office buildings, and schools.	4											
B	The type of structure determines how the parts are put together.	4											
C	Modern communities are usually planned according to guidelines.		4										
D	Structures need to be maintained.		4										
E	Many systems are used in buildings.		4										
F	The selection of designs for structures is based on factors such as building laws and codes, style, convenience, cost, climate, and function.			4									
G	Structures rest on a foundation.			3		4							
H	Some structures are temporary, while others are permanent.					4							
I	Buildings generally contain a variety of subsystems.					4							
J	Infrastructure is the underlying base or basic framework of a system.						4				4		
K	Structures are constructed using a variety of processes and procedures.						4				4		
L	The design of structures includes a number of requirements.									4	4		4
M	Structures require maintenance, alteration, or renovation periodically to improve them or to alter their intended use.									3	4		3
N	Structures can include prefabricated materials									4	4		4

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