STEAM+ Curriculum - Unit #8

Sustainable Systems and Designing a Classroom Greenhouse

Virginia L.J. Bolshakova & Benjamin D. Reinhart
Purdue University

1.0 Introduction

1.1 Overview of STEAM Plus Curriculum

STEAM Plus is an integrated science, technology, engineering, arts, and mathematics (STEAM) focused curriculum that is organized around the STEM Road Map real-world themes (Johnson, Peters-Burton, and Moore, 2015) as an effective way to teach STEAM anchored in some of the critical challenges of society today. The STEM Road Map (Johnson et al., 2015) organizes instruction around five STEM themes that purposefully include big ideas in science, technology, engineering, mathematics, while also including a focus on history, communication, the arts, and 21st Century Skills. The five STEM Road Map themes include: Cause and Effect, Innovation and Progress, The Represented World, Sustainable Systems, and Optimizing the Human Experience. The STEM Road Map themes are described in detail in the next sections.

1.1.1 Cause and Effect

The concept of Cause and Effect is a powerful and pervasive notion in the STEM fields. It is the foundation of understanding how and why things happen as they do. Humans spend considerable effort and resources trying to understand the causes and effects of natural and designed phenomena to gain better control over events and environment and to be prepared to react appropriately. Equipped with the knowledge of a specific cause and effect relationship, we can lead better lives or contribute to the community by altering the cause, leading to a different effect. For example, if a person recognizes that irresponsible energy consumption leads to global climate change, that person can act to remedy their contribution to the situation. Although cause and effect is a core idea in the STEM fields, it is actually very difficult to determine. Students should similarly be capable of understanding when evidence points to cause and effect as well as when evidence points to relationships but not direct causality. The major goal of education is to foster students to be empowered, analytic thinkers, capable of thinking through complex processes to make important decisions. An understanding of causality, as well as understanding when causality cannot be determined, will help students become better consumers, global citizens, and community members.

1.1.2 Innovation and Progress

The theme of Innovation and Progress as conceptualized for the STEM Road Map consists of ideas that use established concepts to move the STEM fields forward. One of the most important factors in determining if humans will have a positive future is innovation. Innovation is the driving force behind progress, which helps to create possibilities that did not exist before. Innovation and progress are creative entities, but in the STEM fields, they are anchored by evidence and logic. In creating something new, students must consider what is already known in the STEM fields and apply this knowledge appropriately. When we innovate, we create value that was not there previously, and create new conditions and possibilities for even more innovations. Students should consider how their innovations might affect progress and use their STEM thinking to change current human burdens to benefits. For example, if we develop more efficient cars that use by-products from another manufacturing industry, such as food processing, then we have used waste productively and reduced the need for the waste to be hauled away, an indirect benefit of the innovation.

1.1.3 The Represented World

When we communicate about the world we live in, how the world works, and how we can meet the needs of humans, sometimes we can use the actual phenomena to explain a concept. Sometimes, however, the concept is too big, too slow, too small, too fast, or too complex for us to explain using the actual phenomena, and we must use a representation or a model to help communicate the important features. We need representations and models such as graphs, tables, mathematical expressions, and diagrams because it makes our thinking visible. For example, when examining geologic time, we cannot actually observe the passage of such large chunks of time, so we create a timeline or a model that uses a proportional scale to visually illustrate how much time has passed for different eras. Another example may be something too complex for students in a particular grade level, such as explaining the p subshell orbitals of electrons to 5th graders. Instead, we use the Bohr model, which more closely represents the orbiting of planets and is accessible to 5th graders. When we create models, they are helpful because they point out the most important features of a phenomenon. We also create representations of the world with mathematical functions, which help us to change parameters to suit the situation. Creating representations of phenomenon engages students because they are able to identify the important features of that phenomenon and communicate them directly. Although models may be helpful, they also leave out some of the details that occur with the phenomena. Because models are estimates of a phenomenon, it is important for students to evaluate their usefulness as well as their shortcomings.

1.1.4 Sustainable Systems

We encounter sustainable systems in everything we do. Looking at a garden, we see flowers blooming, weeds sprouting, insects buzzing and various forms of life living within its boundaries. This is an example of an ecosystem, a collection of living organisms that survive together, functioning as a system. From an engineering perspective, the term "systems" is the use of "concepts of component need, component interaction, systems interaction, and feedback. The interaction of subcomponents to produce a functional system is a common lens used by all engineering disciplines for understanding, analysis, and design." (Koehler, Faraclas, Giblin, Moss & Kazarounian, 2013, p. 8). Systems can either be open (an ecosystem, for example) or closed (a combustion engine, for example). Ideally, a system should be sustainable (e.g., able to maintain equilibrium without much energy from outside the structure). In our example of an ecosystem, the interaction of the organisms within the system and the influences of the environment (e.g., water, sunlight) can maintain the system for a period of time, thus demonstrating its ability to endure. Sustainability is a desirable feature of a system since it allows for existence of the entity for the long-term. In the STEM Road Map project, we identified different standards that we consider to be oriented toward "systems" that students should know and understand in the K12 setting. Included in this systems-thinking are examples such as: ecosystems, the rock cycle, earth processes (such as erosion, tectonics, ocean currents, weather phenomena), Earth-Sun-Moon cycles, heat transfer, and the interaction between the geosphere, biosphere, hydrosphere, and/or atmosphere. Students and teachers should understand that we live in a world of systems and that they are not independent of each other but rather are intrinsically linked so that disruption in one part of the system will have reverberating effects on other parts of the system.

1.1.5 Optimizing the Human Experience

The theme of Optimizing the Human Experience as conceptualized for the STEM Road Map consists of the notion that science, technology, engineering, and mathematics as disciplines have the capacity to continuously improve the ways humans live, interact, and find meaning in the world. This idea has two components: being more suited to our environment and being more fully human. For example, the progression of STEM ideas can help humans live more comfortably by providing unique ways to access water sources, designing energy sources with minimal impact on our environment, developing new ways of communication and expression, and building efficient shelters. STEM ideas can also help humans to be self-actualized by providing access to the secrets and wonders of nature. Learning in STEM requires students to think logically and systematically, which is a way of knowing the world that is markedly different from knowing the world as an artist. When students can utilize various ways of knowing, and understand when it is appropriate to use a different way of knowing or integrate ways of knowing, they are fully experiencing the best of what it is to be human. Learning to think like a STEM professional via the problem-based learning scenarios provided in the STEM Road Map helps students to optimize the human experience by innovating improvements in the designed world students live in as well as helping students develop ways of thinking like a STEM professional to ask questions and design solutions.

1.2 STEAM+ and Problem-Based Learning

The STEAM Plus curriculum uses problem-based learning as the main instructional strategy. The role of teachers in problem-based learning classrooms is that of a facilitator, not as the provider of knowledge. The role of students is to work as a team as they move through planned activities facilitated by the teacher that build their integrated STEAM knowledge and skills to enable them to come up with a viable solution to the problem or product. Students learn and apply the necessary STEAM content as they move through the process of solving the problem. Problem-based learning requires students to work in groups of two to four students and the instructional sequence begins with the student teams receiving a problem or challenge for them to solve related to the STEAM content focus of the unit. After the problem is presented in the first session of the unit, student teams work together through a series of sessions that help them to research the problem, recall prior knowledge of STEAM concepts and skills learned in their regular content discipline classes, build deeper understandings of integrated STEAM content, brainstorm and plan a solution to the problem, design and construct the product, and present the product to consumers and/or the appropriate audience. Educational research on the use of problem-based learning has linked the use of this strategy to deeper conceptual understanding of important disciplinary content, as well as much longer retention of knowledge. Additionally, students who learn in a problem-based learning type of environment are also much more likely to master 21st Century Skills required for the success in college, the workplace, and life.

The STEAM Plus curriculum is specially designed for classrooms to be manageable, even with larger classroom sizes of more than 40 students. Most work within the unit is arranged for student teams of four students. The STEAM classroom should be arranged so that the student teams work at a collaborative table – or so that individual student desks are placed together in a pod. Each student team will develop their own identity for each unit and will work toward common objectives and goals.

It is important to remember that the teacher's role is much different in a problem-based learning than in more traditional classroom settings. The teacher in the problem-based learning classroom spends the majority of his or her time moving around the room and engaging in discussions with student teams and facilitating their work and team discussions. It is expected that the sound volume in a STEAM class will be higher than in a typical classroom, since most of the activities require students to discuss and brainstorm ideas with their teammates in class sessions. The key is to make sure that these conversations are productive, and by moving around the room the teacher will be able to help students adapt to their new roles. In a problem-based learning classroom, students learn a great deal from their peers as well as from the teacher, greatly enhancing the learning that occurs. Finally, the most important piece of advice for teachers new to problem-based learning is to relax and give themselves and their students some time to adapt to the new roles. After the first couple of weeks teachers typically see that things will become more routine and students will greatly excel and enjoy learning in this manner. The best reward is that students will no longer ask "why are we learning this?", since each day they will see the clear connections between what they are learning and the real world they live in.

1.3 STEAM Research Notebook

The STEAM Research Notebook is a tool that allows students to capture their ideas, questions, observations, reflections, evidence of progress, and other items associated with their daily work as a STEM-ist. At the beginning of each unit the students will set up their STEAM Research Notebooks. Students will develop their own tables of contents. There are many activities within the STEAM Plus units that include questions or reflections for students to which students will respond in their STEAM Research Notebooks. The STEAM Research Notebook is designed to be a formative assessment tool used in each session of the unit. The STEAM Research Notebook can also be used as a mechanism for discussion between the teacher and student.

1.4 Engineering Design Process

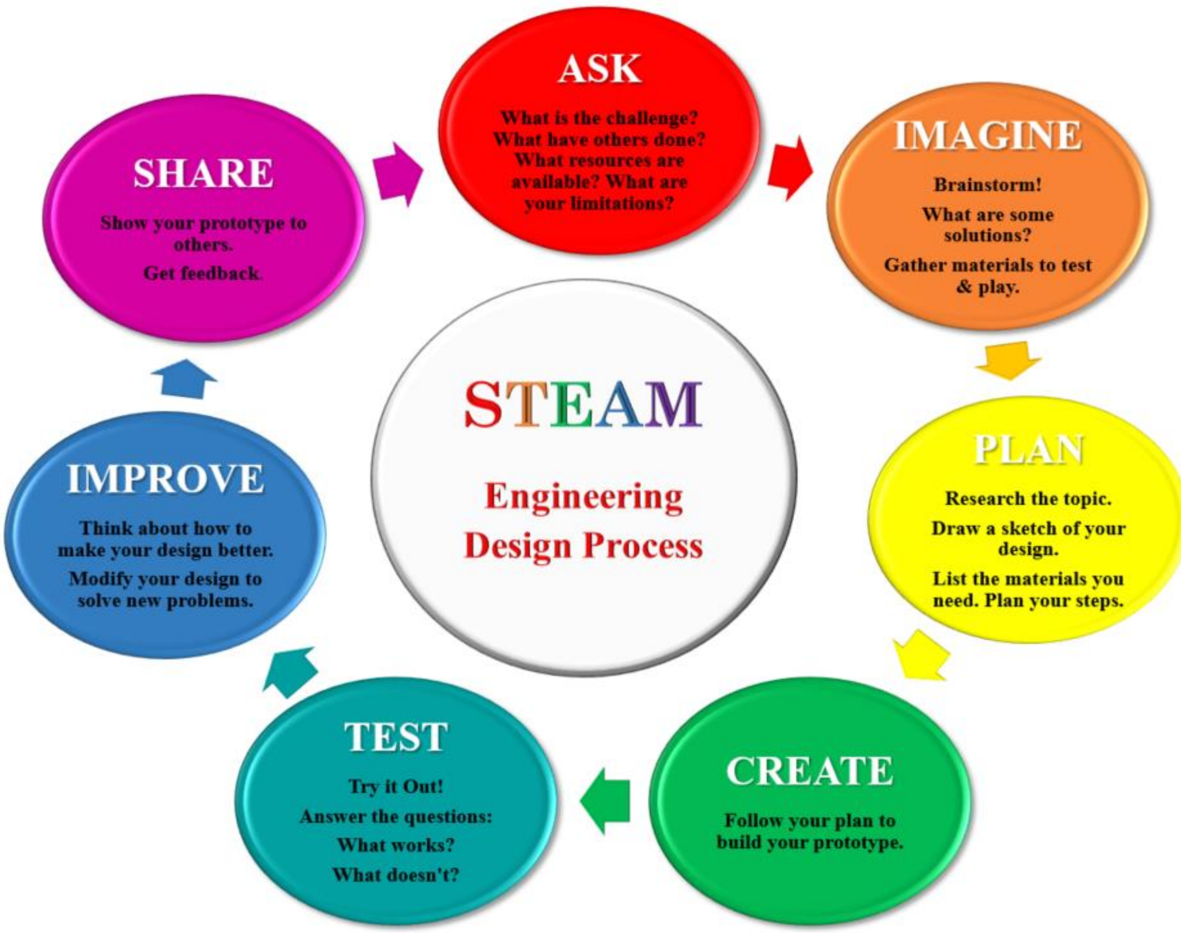
Using problem solving to integrate STEM teaching across disciplines allows students to apply critical thinking skills to a common problem using a variety of disciplinary perspectives. Students will use the engineering design process (EDP) to address challenges and fine-tune their critical thinking strategies throughout the STEAM Plus units. Using the EDP, they will learn that there are many right answers to a problem and that wrong answers are also helpful in shaping their understanding.

To meet certain criteria and/or accomplish a particular task, engineers often design a product (like a new fastener or a computer code). Engineers follow a series of steps called the engineering design process (EDP) to solve problems. The steps of the EDP are:

- **ASK:** Define the problem. Answer the questions: What is the problem? How have others approached it? Identify the requirements.
- **IMAGINE:** Brainstorm possible solutions and find the best solution.
- **PLAN:** Conduct research, list materials needed, and identify steps that should be taken.
- **CREATE**: Follow the plan and build a prototype.
- **TEST:** Test the prototype. Answer the questions: What works, what doesn't? What could be improved?
- **IMPROVE:** Redesign to solve problems that came up in testing and retest.
- **SHARE:** Present the prototype to others and ask for feedback. After it has been critiqued, it may be necessary to reconfigure the prototype or design a new prototype.

It is important to note that engineers do not always follow the steps of the EDP in order. It is common for engineers to design something, test it, find a problem, and then go back to an earlier step to make a modification or change the design entirely. This way of working is called iteration.

Figure 1.4: Engineering Design Process Chart



2.0 Unit Overview

Title: Classroom Greenhouse

STEM Road Map Theme - *Sustainable Systems*

2.1 Unit Summary

In this unit, students will work in teams to design and build greenhouse prototypes that can be used in the classroom. Design teams will use the engineering design process to design controlled-environment agriculture (CEA) systems that can support a variety of plants. Activities will include experiments that foster exploration and evaluation of key concepts in CEA systems, and a variety of technology tools such as presentation and 3-D modeling software. At the end of this unit, design teams will develop persuasive presentations to "sell" their greenhouse prototype to the class. Awards will be given in various categories. At the end of this unit design teams will reconvene as a class to develop plans to integrate all greenhouse prototypes into a classroom CEA system.

The STEAM+ curriculum is designed for a STEAM class and is organized as eighteen (18) integrated STEAM sessions of 40 minutes in duration. However, the organization is flexible and more than one session can be taught in a given day if time permits or activities can be extended over greater lengths of time.

2.2 Established Goals/Objectives

By the end of the unit, students will be able to:

- Maintain a STEAM Research Notebook to track their learning
- Use the engineering design process to create solutions to design challenges
- Understand the concept of coupled human and natural systems
- Identify several environmental challenges to agriculture
- Identify and explain the impact of human technologies on natural resources
- Setup and apply experiments to regulate and modify plant growth

- Identify the purpose and components of a Controlled Agriculture Environment (CAE)
- Design and test heat transferring capacity of a model greenhouse
- Apply measurement and analytical skills to create a greenhouse prototype
- Apply geometry and technology skills to draw a scaled greenhouse prototype in a CAD program
- Utilize critical thinking and problem solving skills
- Create a simple budget document
- Create and plan a Greenhouse Management Plan
- Make decisions that consider cost and benefits
- Understand the historical background of agriculture
- Utilize writing skills to communicate ideas to an audience
- Utilize research skills to access and evaluate information about a topic
- Use the arts to communicate ideas in a creative manner
- Identify the basic components of a greenhouse
- Work effectively in teams to solve problems and design products
- Utilize effective communication skills with a variety of audiences
- Research, design, and construct a greenhouse prototype that meets a set of criteria
- Redesign products in response to feedback

2.3 Challenge and/or Problem for Students to Solve

In this unit, students will work in design teams to design, construct, and evaluate greenhouse prototypes to produce fruits and/or vegetables for the school cafeteria and serve as educational models of sustainable farming methods for future classroom activities. During session activities, students will learn about a suite of environmental and physical variables and systems that influence plant growth and explore ways to measure and regulate these factors for growing plants. Design teams will utilize experiments and technology within the framework of the engineering design process to design, construct, and evaluate their own greenhouse prototypes based on a standard set of materials. Teams will also develop crop management plans and presentations to showcase their greenhouse prototype designs and compare them with those of their classmates.

2.4 Academic Standards Covered in Unit Session and Supplemental Activities

Science (China)	**Mathematics** **(China)**	**Language Arts** **(U.S. Common Core)**
Material Science 6 . Mechanical energy, sound, light, heat, electricity and magnetism are different forms of energy. 6.2.2 light travels in the air in a straight line; When the light in the encounter will reflect the object, it will change the direction of light transmission, will form a shadow. 6.3.1 with temperature to represent the degree of hot and cold objects, degrees Celsius is a unit of measurement of temperature. 6.3.3 Heat can be transferred between objects and objects, usually from high temperature objects to low temperature objects. 6.6.1 There are multiple forms of energy in nature 6.6.2 A form of energy can be converted into another form of expression **Life Science**	**Numbers and Number Sense** Write, read, and evaluate expressions in which letters stand for numbers. Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set. Solve real-world and mathematical problems by writing and solving equations of the form $x + p = q$ and $px = q$ for cases in which p, q and x are all nonnegative rational numbers. Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the	**Key Ideas and Details:** CCSS.ELA-LITERACY.RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts. CCSS.ELA-LITERACY.RST.6-8.2 Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. CCSS.ELA-LITERACY.RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks. **Craft and Structure:** CCSS.ELA-LITERACY.RST.6-8.6 Analyze the author's purpose in providing an explanation,

7.Earth is living with different kinds of creatures. 7.3 There are different plants on the earth, different plants have many different characteristics, the same plant there are individual differences. 8.Plants can adapt to the environment, can create and obtain nutrients to maintain their own survival 8.1 Plants have a structure for obtaining and producing nutrients. 12.There is an interdependence between plants and animals, between animals and plants and the environment. 12.1 Animals and plants have basic survival needs, such as air and water; animals also need food, plants also need light, habitat can meet the basic needs of biological. 12.2 The survival of animals depends on plants, and some animals eat other animals. 12.3 Animals can have an impact on the survival of plants. 12.4 Natural or human disturbance can cause changes in the habitat, which may have an impact on the number of plant and animal species living	dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation. Interpret and compute quotients of fractions, and solve word problems involving division of fractions by fractions, e.g., by using visual fraction models and equations to represent the problem. Fluently divide multi-digit numbers using the standard algorithm. Understand that positive and negative numbers are used together to describe quantities having opposite directions or values (e.g., temperature above/below zero, elevation above/below sea level, credits/debits, positive/negative electric charge); use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation. Understand a rational number as a point on the number line. Extend number line diagrams	describing a procedure, or discussing an experiment in a text. **Integration of Knowledge and Ideas:** CCSS.ELA-LITERACY.RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). CCSS.ELA-LITERACY.RST.6-8.8 Distinguish among facts, reasoned judgment based on research findings, and speculation in a text. CCSS.ELA-LITERACY.RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. **Text Types and Purposes:** CCSS.ELA-LITERACY.WHST.6-8.2 Write informative/explanatory texts, including the narration of

there. **Space Science** 14.Earth has the atmosphere, water, creatures, soil and rocks, the earth has a crust, mantle and core 14.1 The earth is surrounded by a layer of atmosphere 14.3 Most of the land surface is covered with soil, living creatures. 15.Earth is the home of human existence 15.1 Earth provides a variety of natural resources for human survival. 15.2 Human survival requires different forms of energy. 15.3 Human survival requires a variety of disasters, and human activities affect the natural environment. **Engineering and Technology** 16.People in order to make production and life more convenient, fast, comfortable, creating a rich and colorful artificial world. 16.1 The artificial world is not the same as the natural world. 16.2 Engineering and technology products have changed people's production and life.	and coordinate axes familiar from previous grades to represent points on the line and in the plane with negative number coordinates. Solve real-world and mathematical problems by graphing points in all four quadrants of the coordinate plane. Include use of coordinates and absolute value to find distances between points with the same first coordinate or the same second coordinate Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. Understand the concept of a unit rate a/b associated with a ratio a:b with $b \neq 0$, and use rate language in the context of a ratio relationship. Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalent ratios, tape diagrams, double number line diagrams, or equations. **Statistics, Probability, & Measurement**	historical events, scientific procedures/ experiments, or technical processes. **Production and Distribution of Writing:** CCSS.ELA-LITERACY.WHST.6-8.6 Use technology, including the Internet, to produce and publish writing and present the relationships between information and ideas clearly and efficiently. **Research to Build and Present Knowledge:** CCSS.ELA-LITERACY.WHST.6-8.7 Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. CCSS.ELA-LITERACY.WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and research. **Range of Writing:**

17.The core of technology is invented, is the use and transformation of nature 17.1 Technical inventions usually contain certain scientific principles. 17.2 Technology includes methods, procedures and products that people use and transform naturally. 18.The key to engineering is the design, engineering is the use of science and technology to design, solve practical problems and manufacturing products activities 18.1 Engineering is a systematic and scientific work based on science and technology. 18.2 The core of the project is design 18.3 Engineering design needs to take into account the conditions and constraints that can be used and continue to improve.	Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape. Recognize that a measure of center for a numerical data set summarizes all of its values with a single number, while a measure of variation describes how its values vary with a single number. Display numerical data in plots on a number line, including dot plots, histograms, and box plots. Summarize numerical data sets in relation to their context, such as by reporting a number of observations, describing the nature of the attribute under investication, including how it was measured and its units of measurement. Giving quantitative measures of center (median and/or mean) and variability (interquartile range and/or mean absolute deviation), as well as describing any overall pattern and any striking deviations from the overall pattern with reference to the context in which the data were gathered.	CCSS.ELA-LITERACY.WHST.6-8.10 Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences. **Comprehension and Collaboration:** CCSS.ELA-LITERACY.SL.6.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly. **Presentation of Knowledge and Ideas:** CCSS.ELA-LITERACY.SL.6.4 Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation. CCSS.ELA-LITERACY.SL.6.5

	Geometry and Space Find the area of right triangles, other triangles, special quadrilaterals, and polygons by composing into rectangles or decomposing into triangles and other shapes; apply these techniques in the context of solving real-world and mathematical problems. Represent three-dimensional figures using nets made up of rectangles and triangles, and use the nets to find the surface area of these figures. Apply these techniques in the context of solving real-world and mathematical problems. Draw polygons in the coordinate plane given coordinates for the vertices; use coordinates to find the length of a side joining points with the same first coordinate or the same second coordinate. Apply these techniques in the context of solving real-world and mathematical problems. ▪ Draw points, lines, line segments, rays, angles (right, acute, obtuse), and perpendicular and parallel	Include multimedia components (e.g., graphics, images, music, sound) and visual displays in presentations to clarify information.

	lines. Identify these in two-dimensional figures. ▪ Recognize a line of symmetry for a two-dimensional figure as a line across the figure such that the figure can be folded along the line into matching parts. Identify line-symmetric figures and draw lines of symmetry. ▪ Recognize and describe an isosceles triangle and equilateral triangle. Identify and describe the right angle of a triangle, acute angle of a triangle, and the obtuse angle of a triangle. ▪ Through the observation, operation, knowledge of cuboid, cube, cylinder and cone, to understand the development of cuboid, cube and cylinder; combined with the specific circumstances, to explore and master the box, cube, cylindrical volume and surface area and cone volume calculation method. ▪ In a specific situation, the number can be used to	

	represent the location, and can be used in the square on the number of pairs of positions. Explore and master the circle's circumference and area formula.	

Social Studies (National Council for Social Studies Standards - C3 - College, Career, & Civic Life Framework)	**Fine Arts (U.S. National Core Art Standards)**	**Technology Skills (ISTE Standards for Students)**
Civics D2.Civ.7.6-8. Apply civic virtues and democratic principles in school and community settings. D2.Civ.9.6-8. Compare deliberative processes used by a wide variety of groups in various settings. D2.Civ.10.6-8. Explain the relevance of personal interests and perspectives, civic virtues, and democratic principles when people address issues and problems in government and	**Media Arts** **Creating** MA:Cr1.1.1.6 A. Formulate variations of goals and solutions for media artworks by practicing chosen creative processes, such as sketching, improvising and brainstorming. MA:Cr2.1.1.6 A. Organize, propose, and evaluate artistic ideas, plans, prototypes, and	**Knowledge Constructor** Students critically curate a variety of resources using digital tools to construct knowledge, produce creative artifacts and make meaningful learning experiences for themselves and others. Students: A. plan and employ effective research strategies to locate information and other resources for their intellectual or creative pursuits.

civil society. D2.Civ.14.6-8. Compare historical and contemporary means of changing societies, and promoting the common good. **Economics** D2.Eco.1.6-8. Explain how economic decisions affect the well-being of individuals, businesses, and society. D2.Eco.2.6-8. Evaluate alternative approaches or solutions to current economic issues in terms of benefits and costs for different groups and society as a whole. D2.Eco.3.6-8. Explain the roles of buyers and sellers in product, labor, and financial markets. D2.Eco.7.6-8. Analyze the role of innovation and entrepreneurship in a market economy D2.Eco.8.6-8. Explain how	production processes for media arts productions, considering purposeful intent. MA:Cr1.1.1.7 A. Produce a variety of ideas and solutions for media artworks through application of chosen inventive processes, such as concept modeling and prototyping. MA:Cr2.1.1.7 A. Design, propose, and evaluate artistic ideas, plans, prototypes, and production processes for media arts productions, considering expressive intent and resources. **Producing** MA:Pr5.1.6 A. Develop a variety of artistic, design,	B. evaluate the accuracy, perspective, credibility and relevance of information, media, data or other resources. C. curate information from digital resources using a variety of tools and methods to create collections of artifacts that demonstrate meaningful connections or conclusions. D. build knowledge by actively exploring real-world issues and problems, developing ideas and theories and pursuing answers and solutions **Innovative Designer** Students use a variety of technologies within a design process to identify and solve problems by creating new,

external benefits and costs influence market outcomes. **Geography** D2.Geo.1.6-8. Construct maps to represent and explain the spatial patterns of cultural and environmental characteristics. D2.Geo.2.6-8. Use maps, satellite images, photographs, and other representations to explain relationships between the locations of places and regions, and changes in their environmental characteristics. D2.Geo.3.6-8. Use paper based and electronic mapping and graphing techniques to represent and analyze spatial patterns of different environmental and cultural characteristics. D2.Geo.4.6-8. Explain how cultural patterns and economic decisions influence environments and the daily lives of people in both nearby and	technical, and soft skills through performing various assigned roles in producing media artworks, such as invention, formal technique, production, self-initiative, and problem-solving. B. Develop a variety of creative and adaptive innovation abilities, such as testing constraints, in developing solutions within and through media arts productions. C. Demonstrate adaptability using tools and techniques in standard and experimental ways in constructing media artworks. MA:Pr6.1.6	useful or imaginative solutions. Students: A. know and use a deliberate design process for generating ideas, testing theories, creating innovative artifacts or solving authentic problems. B. select and use digital tools to plan and manage a design process that considers design constraints and calculated risks. C. develop, test and refine prototypes as part of a cyclical design process. D. exhibit a tolerance for ambiguity, perseverance and the capacity to work with open-ended problems **Creative Communicator** Students communicate clearly

distant places. D2.Geo.5.6-8. Analyze the combinations of cultural and environmental characteristics that make places both similar to and different from other places. D2.Geo.6.6-8. Explain how the physical and human characteristics of places and regions are connected to human identities and cultures. D2.Geo.7.6-8. Explain how changes in transportation and communication technology influence the spatial connections among human settlements and affect the diffusion of ideas and cultural practices. D2.Geo.8.6-8. Analyze how relationships between humans and environments extend or contract spatial patterns of settlement and movement. D2.Geo.9.6-8. Evaluate the influences of long-term human-	A. Analyze various presentation formats and fulfill various tasks and defined processes in the presentation and/or distribution of media artworks. B. Analyze results of and improvements for presenting media artworks. **Responding** MA:Re7.1.6 A. Identify, describe, and analyze how message and meaning are created by components in media artworks. B. Identify, describe, and analyze how various forms, methods, and styles in media artworks manage audience experience. **Connecting**	and express themselves creatively for a variety of purposes using the platforms, tools, styles, formats and digital media appropriate to their goals. Students: A. choose the appropriate platforms and tools for meeting the desired objectives of their creation or communication. B. create original works or responsibly repurpose or remix digital resources into new creations. C. communicate complex ideas clearly and effectively by creating or using a variety of digital objects such as visualizations, models or simulations. D. publish or present content that customizes

induced environmental change on spatial patterns of conflict and cooperation. D2.Geo.10.6-8. Analyze the ways in which cultural and environmental characteristics vary among various regions of the world. **History** D2.His.1.6-8. Analyze connections among events and developments in broader historical contexts. D2.His.2.6-8. Classify series of historical events and developments as examples of change and/or continuity. D2.His.3.6-8. Use questions generated about individuals and groups to analyze why they, and the developments they shaped, are seen as historically significant. D2.His.5.6-8. Explain how and why perspectives of people have	MA:Cn10.1.6 A. Access, evaluate, and use internal and external resources to create media artworks, such as knowledge, experiences, interests, and research.	the message and medium for their intended audiences.

changed over time.		

2.5 Core Competencies of Chinese Students Included in Unit Session and Supplemental Activities

Cultural Foundation	**1.1 Humanities** ● *Humanities accumulation:* have the basic knowledge of humanities both home and abroad; to understand and master the humanities thought and its methods and practice methods. ● *Humanistic feelings:* a people-oriented consciousness, respect, safeguard human dignity and value; can be concerned about human survival, development and happiness. ● *Aesthetic taste:* the accumulation of artistic knowledge, skills and methods; to understand and respect the diversity of arts and culture, with the discovery, perception, appreciation, evaluation ability and consciousness; a healthy aesthetic value orientation; with artistic expression and creative performance of interest and awareness, can be extended in life. **1.2 Scientific spirit** ● *Rational thinking:* respect for the truth, can understand and master the basic scientific principles and methods; respect for facts and evidence, there is empirical and rigorous sense of knowledge; clear logic, can use scientific thinking to understand things and solve problems. ● *Critical question:* a sense of problem; independent thinking, independent judgment; careful thinking, multi-angle, dialectical analysis of the problem, can make choices and decisions.

	● *Courage to explore:* have curiosity and imagination to discover the world; not be afraid of difficulties, there is a persistent spirit of exploration; can boldly and actively seek effective solutions to problems and so on.
Self-Development	**2.1 Learn to Learn** You can learn and understand the value of learning, have a positive attitude and a strong interest in learning; to develop good learning habits, to master their own learning methods; to self-study, with a lifelong learning awareness and Ability and so on. ● *Diligent reflection:* a sense of habit of learning their own state of study and habits, good at summing up experience; according to different situations and their own reality, select or adjust the learning strategies and methods. ● *Information awareness*: to consciously and effectively access, asses, identify, use information; with digital viability, take the initiative to adapt to the "Internet +" and other social information development trends; have network ethics and information security awareness. **2.2 Healthy lifestyle** ● *Cherish life:* to understand the meaning of life; with safety awareness and self-protection ability; to master their own sports methods and skills to develop healthy and civilized behavior habits and lifestyle. ● *Perfect personality:* a positive psychological quality, self-confidence, self-control, to regulate and manage their own emotions, with anti-setbacks and so on. ● *Self-management:* to correctly understand and assess the self, according to their own personality, potential to choose the appropriate direction of development; rational distribution and use of time and energy; with the goal of sustained action.

Social **Participation**	**3.1 Responsibility to Play** ● *Social responsibility:* self-esteem self-discipline, civilized and courteous, honest and friendly; participate public service and volunteer service, dedicated dedication, team spirit and mutual help; can take the initiative, Self-respect and respect for nature, with a green lifestyle and sustainable development concept. ● *International understanding*: a global sense and open mind, to understand the process of human civilization and world development trends; to respect the diversity and diversity of the world's multiculturalism, and actively participate in cross-cultural exchanges; concerned about the global challenges facing mankind, understanding of human fate community and its value. **3.2 Practice innovation** ● *Labor awareness:* respect for labor, with a positive attitude and good labor habits; with hands-on ability to master a certain degree of labor skills; active participation in the housework, production labor, public welfare activities and social practice, try to improve and innovate a successful life. ● *Problem solving:* good at discovering and asking questions, having the interest and enthusiasm to solve the problem; selecting reasonable solutions based on specific situations and specific conditions; having the ability to act in complex environments. ● *Technology use:* understanding organic links of technology and human civilization with the skills to learn and master technology; with engineering thinking, creativity, try to transform programs into tangible objects or existing items to improve and optimize.

2.6 Framework for 21st Century Learning Skills Included in Unit Sessions

21st Century Skills	Learning Skills &	Teaching Strategies	Evidence of Success

	Technology Tools		
Interdisciplinary Themes	- Civic Literacy - Health Literacy - Environmental Literacy - Entrepreneurial Literacy - Engineering Design Process	- Students will conduct experiments to test various factors (light and nutrients) which impact plant growth and greenhouse design. - Students will produce models and read for understanding to better understand ways to improve their community and protect the environment. - Students will explore and use tables and graphs. - Students will complete activities that task students with optimizing crop production schedules based on economic data. - Students will estimate costs associated with	- Students will design greenhouse prototypes which modify and control environmental and physical aspects of plant growth. - Students will be able to compare, contrast, and evaluate greenhouse design and management decisions based on economic constraints and goals. - Students will use models and experiments to demonstrate what they are learning about plants and the environment. - Students will interpret, organize, and present information from activities and research in an effective format

		their greenhouse prototypes. - Students will utilize the EDP and work in teams to design, construct and evaluate solutions for greenhouse prototypes.	that demonstrates understanding of plants, including plant needs, life cycles, and how they are used in our lives.
Learning and Innovation Skills	- Creativity & Innovation - Critical Thinking & Problem Solving - Communication - Collaboration	- Students will work individually and in teams to articulate thoughts and ideas and apply concepts in brainstorming, journaling in STEAM Research Notebooks, and design sketching activities. - Students will be tasked to develop greenhouse prototype designs which meet project goals given certain constraints. This will require analyzing various tradeoffs in the design.	- Student STEAM Research Notebooks and sketching activities will contain a wide variety of ideas and design iterations. - Presentations from different design teams will highlight unique design solutions and growing plans. - Greenhouse prototype designs will be complex enough to manage multiple factors of plant growth (e.g. light, temperature, water, nutrients, etc.) while

		- Design Teams will develop and deliver group presentations to communicate about their greenhouse prototype designs and "sell" their design ideas to classmates. - Teach and facilitate creativity by encouraging students to think outside the box to solve problems. - Facilitate group work and instruct students in safe Internet search procedures and strategies.	meeting project constraints. - Students will record their EDP process thinking in multiple formats and work with their teams to share and improve upon their greenhouse prototype designs. - Design teams will interact in activities that reinforce the importance of communication and collaboration.

Information, Media and Technology Skills	- Information Literacy - Media Literacy - ICT Literacy	- Students will gather information during class sessions and activities through lecture, videos, group discussion, hands-on experimentation, and independent research. These information sources will be managed through their STEAM Research Notebooks. - Design Teams will work together to utilize 3-D modeling and presentation software to develop a presentation on their greenhouse prototype designs.	- STEAM Research Notebooks will be comprehensive and well-documented across class sessions and activities. - Students and design teams will be able to utilize technology sources including 3-D modeling software, online search engines for research, and presentation software.
Life and Career Skills	- Flexibility & Adaptability - Initiative & Self-Direction - Social & Cross-Cultural Skills	- Students will complete activities both as individuals and as team members. - Design team activities will include plan of	- Design team projects are completed on time with evidence of participation by all team members.

	- Productivity & Accountability - Leadership & Responsibility	work and delegation of tasks. - Greenhouse prototype designs will be tested, evaluated, and redesigned as necessary based on results. - Scaffold sketch-and-model through a series of inquiry activities and topical research projects. - Use EDP to encourage flexibility (through redesign), time management, and goal setting in structured group work. - Provide guidelines and practice opportunities for students to share, emphasizing being inclusive of all team members.	- Design teams are able to complete activities on time and within constraints and present their design to classmates. - Design team members show full comprehension and understanding of final design and presentation information - Students' presentations include appropriate language and vocabulary. - Students respond to questions regarding their design process and teamwork.

2.7 Prerequisite Key Knowledge and Differentiation Strategies Included in Unit Sessions

Science		
Prerequisite key knowledge	**Application of knowledge**	**Differentiation for students needing knowledge**
- Plants acquire their material for growth chiefly from air and water. - Matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment. - Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space but individuals and communities are doing things to help	- Students design a scale greenhouse prototype to grow plants for school use in the cafeteria and in experiential learning activities. - Identification of controlling factors in plant growth and biogeochemical cycling and how these factors can be controlled. - Greenhouse prototypes are purposefully designed and constructed to provide control over a select number of environmental and physical factors that impact plant growth and productivity while also meeting project constraints.	- Provide background knowledge and examples about controlling factors in plant growth, biogeochemical cycling, and CEA systems. - Provide opportunities to work in teams as students test their ideas and designs. - Provide opportunities for class discussion and individual writing and reflection to explore key concepts. - Review the scientific method and engineering design process. Provide examples of testable questions, experimental designs, and how to best use students' STEAM Research

protect Earth's resources and environments. - Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.	- Identify and answer testable questions about factors that impact plant growth and productivity. - Use scientific measurement and reflection to design and implement experimental designs. - Each student maintains a STEAM Research Notebook that includes pictures, numbers, and words to reflect observations.	Notebooks to document and reflect on observations. - Facilitate student experiments by reviewing step-by-step instructions and checking in throughout the implementation of the design. - Facilitate critical discussions and problem solving through graphic, charting, and guided analysis and evaluation of problems and topics.
Mathematics		
Prerequisite key knowledge	**Application of knowledge**	**Differentiation for students needing knowledge**
Operations and Algebraic Thinking - Write and interpret numerical expressions. - Analyze patterns and relationships. Number and Operations in Base Ten - Understand the place value system.	- Use measurement tools to make measurements and collect data. - Use numbers to report relationships between variables and report numerical quantities to answer simple questions and	- Provide examples of measurement, calculation, graphing/charting, and evaluation procedures. - Provide background information and guidance with high quality support materials, including example products, teacher instruction,

- Perform operations with multi-digit whole numbers and with decimals to hundredths. Number and Operations—Fractions - Use equivalent fractions as a strategy to add and subtract fractions. - Apply and extend previous understandings of multiplication and division to multiply and divide fractions. Measurement and Data - Convert like measurement units within a given measurement system. - Represent and interpret data. - Geometric measurement: understand concepts of volume and relate volume to multiplication and to addition. Geometry	the sample and/or population. - Use appropriate charts and graphs to document results from collected data. - Estimate summary statistics and mathematical descriptors of datasets. - Create graphical models of plant growth. - Use understanding of shapes, lines, symmetry and relational location/rotation when designing and constructing greenhouse prototypes. - Draw scale representations of teams' greenhouse prototypes from a variety of perspectives and take measurements including all four mathematical operations. - Use rulers, scales, measuring cups, and thermometers to	and online videos and/or tutorials. - Provide opportunities to work in groups to learn from peers. - Establish open work times to allow students to practice measurement, calculation, and geometric manipulation skills.

- Graph points on the coordinate plane to solve real-world and mathematical problems. - Classify two-dimensional figures into categories based on their properties.	make observations about plants and growing conditions.	
	Language Arts	
Prerequisite key knowledge	**Application of knowledge**	**Differentiation for students needing knowledge**
Reading - Quote accurately from a text when explaining what the text says explicitly and when drawing inferences from the text. - Determine two or more main ideas of a text and explain how they are supported by key details; summarize the text. - Explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a	Reading - Use provided reference materials, online research, and experimental measurement to learn about plant growth and controlled-environment agriculture concepts. - Describe images, illustrations, and text to better understand and demonstrate key concepts of controlled-environment agriculture and plant growth.	Reading - Provide reading strategies to support comprehension of nonfiction texts such as the use of complementary visualizations and group discussions. - Provide classroom references and lists of important concepts and vocabulary terminology. Writing - Provide recommendations and examples on writing organization.

historical, scientific, or technical text based on specific information in the text. - Determine the meaning of general academic and domain-specific words and phrases in a grade-relevant text. - Analyze multiple accounts of the same event or topic, noting important similarities and differences in the point of view they represent. - Draw on information from multiple print or digital sources, demonstrating the ability to locate an answer to a question quickly or to solve a problem efficiently. - Integrate information from several texts on the same topic in order to write or speak about the subject knowledgeably.	- Apply information from images, illustrations, and text to inform decision making in designing, evaluating, and constructing greenhouse prototypes. Writing - Use grade-level science terminology to inform and explain learning and new ideas about plant growth and controlled-environment agriculture systems. - Complete writing exercises in multiple styles and contexts.	- Provide tools such as rubrics that use a consistent format so students can critique their own writing.

- Know and apply grade-level phonics and word analysis skills in decoding words. - Read with sufficient accuracy and fluency to support comprehension. Writing - Produce clear and coherent writing in which the development and organization are appropriate to task, purpose, and audience. - With guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach. - With some guidance and support from adults, use technology, including the Internet, to produce and publish writing as well as to		

interact and collaborate with others; demonstrate sufficient command of keyboarding skills to type a minimum of two pages in a single sitting. - Conduct short research projects that use several sources to build knowledge through investigation of different aspects of a topic. - Recall relevant information from experiences or gather relevant information from print and digital sources; summarize or paraphrase information in notes and finished work, and provide a list of sources. - Draw evidence from literary or informational texts to support analysis, reflection, and research.		
Communication Skills		

Prerequisite key knowledge	Application of knowledge	Differentiation for students needing knowledge
- Ask questions and carry on a conversation to demonstrate understanding. - Provide evidence and reasoning for decision making.	- Participate in collaborative conversations using appropriate language and skills. - Effectively support scientific knowledge with appropriate language and relevant, descriptive details. - Teams make claims for their greenhouse prototype designs and support the claims with evidence.	- Provide examples of effective communication skills which model appropriate language, structure, and reasoning. - Provide handouts and rubrics to support organization of facts and use of relevant descriptive details.

2.8 Desired Outcomes and Evidence of Success

Desired Outcome	Evidence of Success in Achieving Identified Outcome	
- Students will be able to effectively document ideas, thoughts, and reference information in a STEAM Research Notebook for the purpose of creating original ideas and	**Performance Tasks** - Each student has a completed STEAM Research Notebook documenting their thoughts, ideas, and observations throughout the unit. - STEAM Research Notebooks feature a variety of data types	**Other Measures** - STEAM Research Notebooks will be assessed using a rubric. - Presentation rubrics will be provided to clarify expectations for

products and drawing broad-level conclusions. - Students will be able to clearly express their ideas, thoughts, and greenhouse prototype designs through verbal, written, and visual methods. - Students will be able to apply the engineering design process to solve problems. - Students will design greenhouse prototypes that can be used in the classroom.	(e.g. quantitative, qualitative) and forms of communication (e.g. writing, sketches). - Design team presentations are created by each design team to demonstrate and promote their greenhouse prototypes. - Students will design, test and, build a greenhouse prototype.	communicating student designs. - Students will provide reflection and feedback in their STEAM Research Notebook on unit sessions and activities.

2.9 Unit Map

Session	5 E Stage/EDP Stage	Content	Connection to Challenge	Session Supplies (1 per student unless otherwise noted)
1	Engage/Ask	Presentation of the Challenge	This session will introduce students to the unit challenge and orient them to their STEAM Research Notebooks and design teams. Teams will work together to plant seeds that will be used in future activities and experiments.	• Spiral or composition notebook to serve as STEAM Research Notebook • Pen or Pencils (single or multiple colors) • Highlighters (single or multiple colors) • Tape or Glue *1 per design team:* • Bean seeds (16/team) • 16 oz Plastic cups, red (8/team) • Topsoil or Garden Soil, without added fertilizer • Water • Measuring cup or Graduated cylinder • Clear plastic wrap
2	Explore and Explain/Imagine	Exploring Coupled Human and Natural Systems through Agriculture	Students will begin to explore how natural and human systems are inextricably linked through agriculture production, and discuss how certain human-mediated actions can have positive or negative consequences on natural and human systems (including ecosystem degradation, climate change, and famine).	• STEAM Research Notebook • Pen or Pencils (single or multiple colors)
3	Explore and Explain/Imagine	Water and Energy Cycles	Students will learn about how water and energy moves through various landscapes and how crops and people interact with these cycles through processes such as	• STEAM Research Notebook • Pen or Pencils (single or multiple colors)

			photosynthesis, solar energy, and hydropower as background for creating ideal growing conditions for plants in their greenhouse prototypes.	*1 per design team:* • Measuring Cup or Graduated Cylinder • Weighing Scale (sub-gram accuracy) • Soil Thermometer • 16 oz. plastic cups; Clear (3/design team) • Multipurpose sealing wrap • Tin foil • Tape • Water • Hole punch
4	Explore and Explain/Imagine and Plan	Nitrogen, Phosphorus, and Carbon Cycles	Students will expand on water and energy cycles and learn about the cycling of nutrients and carbon. These are the building blocks of natural systems that support plant growth and productivity and the learning in this session serves as background for creating ideal growing conditions for plants in their greenhouse prototypes.	• STEAM Research Notebook • Pen or Pencils (single or multiple colors) • Elemental fertilizer (e.g. Miracle-Gro All Purpose Food, 1lb) – 1 per class • Organic fertilizer (e.g. Fish-based Plant Fertilizer, 32oz) – 1 per class *1 per design team:* • Measuring cup or Graduated cylinder • Mixing cup • Weighing scale • Soil Thermometer • Measuring spoons, ¼ tsp. And 1 tsp. • Calculator

5	Explore and Explain/Imagine and Plan	Ecosystem Services Everywhere	Students will learn about the benefits the natural world bring to our households, communities, and economies through ecosystem services. Activities will engage students in identifying and describing services they see in their own school yard and build their understanding of the interactions between humans and the environment. This prepares students to create ideal growing conditions in their greenhouses and to be able to "sell" their greenhouse prototype designs effectively.	• STEAM Research Notebook, • Pen or Pencils (multiple colors) *1 per design team:* • Soil Thermometer • Weighing Scale • Ruler • Water • Scissors • Tablet or Digital Camera (optional)
6	Explore and Explain/Imagine and Plan	Crops and Soils	In this session students will be introduced to the idea of soil being the growth medium for plants and the area where they access water, nutrients, and space for growth. Students will investigate soil samples and conduct experiments on the water holding capacity of different soils to prepare them to create ideal growing conditions in their greenhouse prototypes.	• STEAM Research Notebook • Pen or Pencils (single or multiple colors) • One quart jars with tight covers and blank labels (1 per student) *1 per design team*: • Newspaper or plastic to cover tables • Soil collection kit for each student • Soil-water filter (see Soil Filter Image) • Hand spade or large spoon • Digital camera • Magnifying glasses, tweezers, utensils, and other small tools for teams to share • Reference books for identification of plants,

				insects, rocks, and minerals (shared with the group) • Soil Thermometer • Weighing Scale • Ruler • Water • Paper plate • Microscopes (Optional)
7	Explore and Explain/Imagine and Plan	Crops and Climates	In this session students will be engaged in exploring how crops and climate are related. Session activities will let students explore some the environmental factors that affect crop yields in order to prepare them to create ideal growing conditions in their greenhouse prototypes.	• STEAM Research Notebook • Pen or Pencils (single or multiple colors) *1 per design team*: • Soil Thermometer • Weighing Scale • Ruler • Water
8	Explore and Explain/Imagine and Plan	Controlled-Environment Agriculture	Students will learn about different types of controlled-environment agriculture systems, such as greenhouses and hydroponics. Students will work together in their design teams to construct their own hydroponics system.	• STEAM Research Notebook • Pen or Pencils (single or multiple colors) *1 per design team*: • 2-liter bottle • Coconut coir fiber • Wicks • Aluminum foil • pH kit • Measuring cup and spoons • Nutrients for hydroponic systems • 5 Lettuce seeds (or other leafy vegetable) • Marker • Scissors

				• Soil Thermometer • Weighing Scale • Ruler • Water
9	Explore and Explain/Imagine and Plan	Designing and Managing Controlled-Environment Agriculture Systems	Students will learn about requirements and considerations in designing and managing CEA systems such as greenhouses. During the activity, design teams will work together to develop growing plans to achieve various goals given different scenario constraints. This prepares students to create a greenhouse management plan for their greenhouse prototypes.	• STEAM Research Notebook • Pen or Pencils (single or multiple colors) • Calculator • Scratch paper for calculations *1 per design team*: • Soil Thermometer • Weighing Scale • Ruler • Water
10	Explore and Extend/Plan and Create	Heat and Classroom Greenhouse Prototype Design - Session I	Students will briefly be introduced to one last environmental condition that is critical to greenhouse design - heat, which is controlled through the processes of radiation and transmittance, absorption, and convection. This prepares students to create a greenhouse prototype with an appropriate heat management system. Students will begin the process for their greenhouse prototype and be presented with the specifications and constraints for their designs.	• STEAM Research Notebook • Pen or Pencils (multiple colors) *Student greenhouse prototype materials (1 per design team):* • Structural Frame must be made of wood, metal, or plastic (pvc pipes) • Acrylic or Plexiglas or Plastic for wall coverings • Hot glue gun or glue sticks, expandable glue (e.g. Gorilla Glue), tape, and nails • Hammer, saws, stapler • Soil and plants • Thermometer

				• Tools to share (saws, hammers, etc.)
11	Extend/Plan and Create	Classroom Greenhouse Prototype Design -Session II	Students will review the Classroom Greenhouse Design Challenge criteria, objectives, and constraints. The majority of Session Eleven will be spent individually on the Imagine and Plan stage of the engineering design process through sketching and 3-D modeling.	• STEAM Research Notebook • Pen or Pencils (multiple colors) • Access to Tinkercad: https://www.tinkercad.com/learn/ *Student greenhouse prototype materials (1 per design team)* - • See Session Ten materials
12	Extend/Plan and Create	Classroom greenhouse prototype Design Session III	Students will gather with their design teams to share and discuss their ideas and sketches for their greenhouse prototypes. Design teams will identify a desired solution and develop a Design Team Action Plan and delegate tasks.	• STEAM Research Notebook • Pen or Pencils (multiple colors) *Student greenhouse prototype materials (1 per design team)* - • See Session Ten materials
13	Extend/Plan and Create	Greenhouse prototype Build Day I	Using the design sketch each team created, student groups will begin building their prototypes along with working on project documentation (e.g. materials budget, Tinkercad scaled drawing, etc.).	• STEAM Research Notebook • Pen or Pencils (multiple colors) *Student greenhouse prototype materials (1 per design team)* - • See Session Ten materials
14	Extend/Plan and Create	Greenhouse prototype Build Day II		
15	Extend and Evaluate/Create, Test, and Improve	Greenhouse Temperature Experiments and Growing Plan	Students will work as a design team to conduct heat transfer experiments on their greenhouse prototypes to test their ability to absorb and maintain radiant energy. Design teams will develop their Crop Management Plans.	• STEAM Research Notebook • Pen or Pencils (multiple colors) *1 per design team:* • Digital Presentation Software (e.g. PowerPoint, Prezi, Slides, etc.)

				• Greenhouse prototype • Soil • Tool to scoop soil • 2 thermometers • Incandescent lamps (if greenhouses cannot be tested outdoors in the sun)
16	Extend and Evaluate/Create and Share	Greenhouse Challenge Presentation Development	Students will synthesize their learning and their engineering design process activities for the development of their greenhouse prototype into a digital presentation.	• STEAM Research Notebook • Pen or Pencils (multiple colors) • Digital Presentation Software (e.g. PowerPoint, Prezi, Slides, etc.) *1 per design team:* • Greenhouse prototype
17	Extend/Share and Ask	Greenhouse Challenge Presentation Day	Students 'sell' their greenhouse prototype to the class by demonstrating their engineering design process and their greenhouse prototype.	• STEAM Research Notebook • Pen or Pencils (multiple colors) • Digital Presentation Software (e.g. PowerPoint, Prezi, Slides, etc.) • Projector, Audio/Video Needs for Presentation Display (1 per class) *1 per design team:* • Greenhouse prototype • Greenhouse presentation
18	Explore and Explain/Imagine and Plan	Synthesis of Unit Sessions and Challenge	Students and teacher will review feedback from the student presentations and award certificates to the top presentations. The class will discuss plans to integrate and maintain the greenhouse prototypes in the classroom.	• STEAM Research Notebook • Pen or Pencils (multiple colors)

Session	5 E Stage/EDP Stage	Content	Connection to Challenge	Session Supplies (1 per student unless otherwise noted)
1	Engage/Ask	Presentation of the Challenge	This session will introduce students to the unit challenge and orient them to their STEAM Research Notebooks and design teams. Teams will work together to plant seeds that will be used in future activities and experiments.	
2	Explore and Explain/Imagine	Exploring Coupled Human and Natural Systems through Agriculture	Students will begin to explore how natural and human systems are inextricably linked through agriculture production, and discuss how certain human-mediated actions can have positive or negative consequences on natural and human systems (including ecosystem degradation, climate change, and famine).	
3	Explore and Explain/Imagine	Water and Energy Cycles	Students will learn about how water and energy moves through various landscapes and how crops and people interact with these cycles through processes such as photosynthesis, solar energy, and hydropower. Students will set up their first experiment.	
4	Explore and Explain/Imagine and Plan	Nitrogen, Phosphorus, and Carbon Cycles	Students will expand on water and energy cycles to introduce students to the cycling of nutrients and carbon. These are the building blocks of natural systems that support plant growth and productivity. Students will set up their second experiment.	
5	Explore and Explain/Imagine and Plan	Ecosystem Services Everywhere	Students will learn about the benefits the natural world bring to our households, communities, and economies through ecosystem services. Activities will engage students in identifying and describing services they see in their own school yard.	
6	Explore and Explain/Imagine and Plan	Crops and Soils	In this session students will be introduced to the idea of soil being the growth medium for plants and the area where they access water, nutrients, and space for growth. Students will investigate soil samples and conduct experiments on the water holding capacity of different soils.	

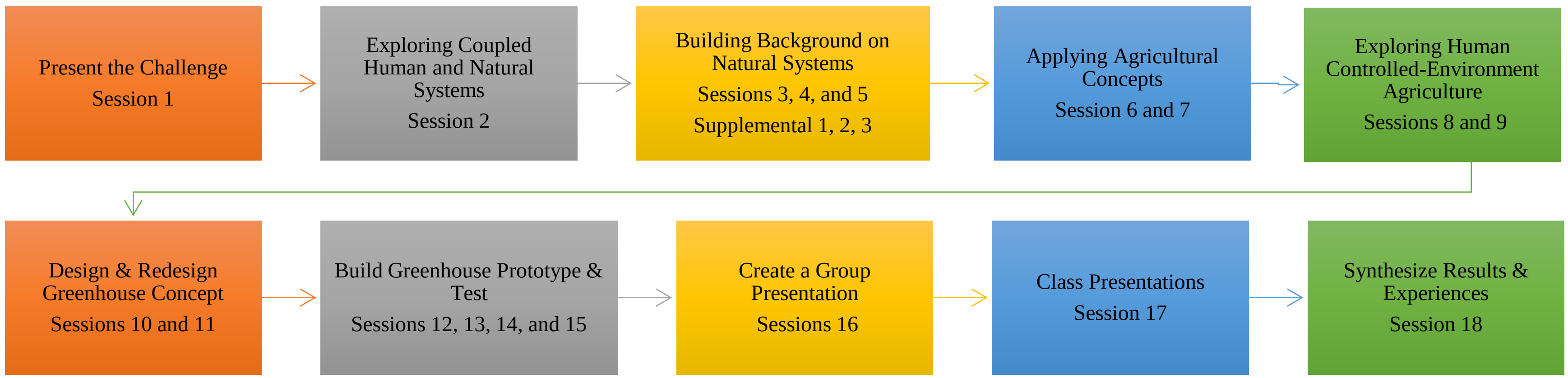
7	Explore and Explain/Imagine and Plan	Crops and Climates	In this session students will be engaged in exploring how crops and climate are related. Session activities will let students explore some the environmental factors that affect crop yields.	
8	Explore and Explain/Imagine and Plan	Controlled-Environment Agriculture	Students will learn about different types of controlled-environment agriculture systems, such as greenhouses and hydroponics. Students will work together in their design teams to construct their own hydroponics system.	
9	Explore and Explain/Imagine and Plan	Designing and Managing Controlled-Environment Agriculture Systems	Students will learn about requirements and considerations in designing and managing CEA systems such as greenhouses. During the activity, design teams will work together to develop growing plans to achieve various goals given different scenario constraints.	
10	Explore and Extend/Plan and Create	Heat and Classroom Greenhouse Prototype Design - Session I	Students will briefly be introduced to one last environmental condition that is critical to greenhouse design - heat, which is control through the processes of radiation and transmittance, absorption, and convection. Students will begin the process for their greenhouse prototype and be presented with the specifications and constraints for their design.	
11	Extend/Plan and Create	Classroom Greenhouse Prototype Design -Session II	Students will review the Classroom Greenhouse Design Challenge criteria, objectives, and constraints. The majority of Session Eleven will be spent individually on the Imagine and Planning stage of the engineering design process through sketching and 3-D modeling.	
12	Extend/Plan and Create	Classroom greenhouse prototype Design Session III	Students will gather with their design teams to share and discuss their ideas and sketches for their greenhouse prototypes. Design teams will identify a desired solution and develop a Design Team Action Plan and delegate tasks.	
13	Extend/Plan and Create	Greenhouse prototype Build Day I	Using the design sketch each team created, student groups will begin building their prototype along with working on project documentation (e.g. materials budget, Tinkercad scaled drawing, etc.).	
14	Extend/Plan and Create	Greenhouse prototype Build Day II		

15	Extend and Evaluate/Create, Test, and Improve	Greenhouse Temperature Experiments and Growing Plan	Students will work as a design team to conduct heat transfer experiments on their greenhouse prototypes to test their ability to absorb and maintain radiant energy. Design teams will develop their Crop Management Plans.	
16	Extend and Evaluate/Create and Share	Greenhouse Challenge Presentation Development	Students will pull together all their engineering design process activities for the development of their greenhouse prototype into a 10-minute digital presentation.	
17	Extend/Share and Ask	Greenhouse Challenge Presentation Day	Students 'sell' their greenhouse prototype to the class by demonstrating their engineering design process and their greenhouse prototype.	
18	Explore and Explain/Imagine and Plan	Synthesis of Unit Sessions and Challenge	Students and teacher will review feedback from the student presentations and award certificates to the top presentations. The class will discuss plans to integrate and maintain the greenhouse prototypes in the classroom.	

Figure 2.10: Visual Graphic of Unit Components

Grade 6 - Classroom Greenhouse Unit

Connections Between STEAM Sessions One - Eighteen and Supplemental STEAM Content Activities



STEAM + Unit 8: Classroom Greenhouse Grade 6

3.0 Session Plans

In this unit, students will work in design teams to design and build greenhouse prototypes that can be used in the classroom. Design teams will use the engineering design process (EDP) to design a controlled-environment agriculture (CEA) growing system that can support a variety of plants under a variety of conditions and do so in a way that has few environmental impacts. Design teams will apply knowledge used during the unit sessions to design, construct, evaluate, and present greenhouse prototypes.

3.1 SESSION ONE - Presentation of the Challenge - 40 minutes

This session will introduce students to the unit challenge and orient them to their STEAM Research Notebooks and design teams. Teams will work together to plant seeds in various types of containers. These plants will be used in future activities and experiments to help students evaluate how plants grow and interact with their environment and to build background for designing growing conditions in their greenhouse prototypes.

3.1.1 Teacher Preparation, Session 1

The teacher should assemble materials, duplicate handouts, and preview videos used in the session. The teacher should be prepared to introduce the unit's challenge, and should understand the requirements for the classroom greenhouse design challenge. It would be be best for teacher to familiarize themselves with various types of greenhouses (e.g. design types, construction materials, and general opereation procedures) as there are many and the goals and objectives for each school project may be different. The Univeristy of Arizona's Controlled Environment Agriculture (CEA) Center provides an extensive online resource for research, instruction, and extension for producint crops with sustainability, efficiency, and eco-friendliness in mind at http://ceac.arizona.edu/.

Careful planning ahead of time will maximize the experience for the students and the school community. For example, identifying volunteers from the school and community to help support students with the design and construction element of the greenhouse might be favorable. It would also be beneficial to review the STEAM careers that are associated with the Sustainable Systems and Designing a Classroom Greenhouse Unit are described in section 4.3 of Appendix B. Careers may be integrated into the unit through various means such as through role play or by introducing the careers throughout the unit and encouraging students to adopt the role of one or more of the careers in the sessions.

Session one begins the first steps in the bean plant experiments. The teacher should have plastic cups, bean seeds, soil, and water available for students to begin their experiments as well as set aside space for the students to gain easy access to make observations and manipulative experiments each week.

Teacher Materials:

Example Title Page

Example Table of Contents

Digital Resources:

Controlled-environment agriculture video (https://www.youtube.com/watch?v=gxUSyoeOksg)

Student Materials:

Spiral or composition notebook to serve as STEAM Research Notebook

Pen or Pencils (single or multiple colors)

Highlighters (single or multiple colors)

Tape or Glue

Other Materials (1 per design team):

Bean seeds (16/team)

16 oz Plastic cups, red (8/team)

Topsoil or Garden Soil, without added fertilizer

Water

Measuring cup or Graduated cylinder

Clear plastic wrap

Grow light, if window is not available

Handouts:

Unit Challenge Description

Engineering Design Process (EDP)

Notebook Tips

Types of Greenhouses

Notebook Grading Rubric

Table 3.1 Explicit Knowledge Required for Session 1

Core Area	Knowledge Required	Supports for Student Learning
Science	Students should understand that the key to engineering is the design. Engineering uses science and technology to solve practical problems by designing solutions and manufacturing products and processes.	Teacher introduces the engineering design process (EDP) to students, providing an opportunity to discuss the process of engineering.
	Nature of scientific inquiry. Students should understand that scientists ask questions and use observations and measurements through thoughtfully designed inquiries to collect data about their questions. Scientists keep records of the data they collect and their ideas in scientific notebooks.	Teachers will review the purpose of the notebook and its format with students and will provide examples of scientists and their work.
Language Arts	Students should understand that a table of contents is a list of a book's content provided before the start of a written work. They should understand that the purpose of a table of contents is to provide a means of organization that allows the reader to easily find information grouped by chapter or section within a book.	Teachers will review the purpose of the table of contents and provide a template for student use.
	Students should understand that rubrics are documents that include criteria for assigned work as well as levels of proficiency associated with those criteria. They should understand that rubrics are used not only used as a guide for teachers to evaluate their work, but that rubrics can be used for self-assessment and to guide their understanding of expectations for their work.	Teachers will review the types of rubrics that will be used in the notebooks and provide rubrics that will be kept in students' notebooks to guide their work throughout the unit.
Social Studies	Students should understand that a consumer is a person whose wants are satisfied by using goods and services. A producer makes goods and/or provides services.	Teachers will read aloud the Unit Challenge Description that challenges students to act as producers of greenhouse prototypes targeted toward consumers. Teachers may wish to emphasize the role of

		producers and consumers in the unit challenge.

3.1.2 Introduction - 10 minutes

To engage with students and give an overview of the unit, teachers will provide students with the handout, Unit Challenge Description. Teachers should read the Unit Challenge Description handout as the students follow along. Following the Unit Challenge Description, the students should watch the Controlled-Environment Agriculture (CEA) video (https://www.youtube.com/watch?v=gxUSyoeOksg).

After introducing the students to the unit challenge, the teacher will introduce the engineering design process (EDP) and the STEAM Research Notebook as the two primary tools that will be used to guide the greenhouse design process. The teacher should use the EDP handout to discuss with students why each step is important and how the STEAM Research Notebooks are used to help document and organize thoughts and data during the implementation of the EDP. The class should then look at the Types of Greenhouses handout to see that a variety of different approaches can be used to achieve the solution of building a greenhouse. The teacher can lead a discussion among the class theorizing under what conditions each of the greenhouse types may be more or less optimal.

Finally, students will be grouped into design teams of 4-5 students in which they will work through each of the subsequent unit sessions to develop and present team greenhouse prototypes. A description of these sessions and activities is included in the Unit Challenge Description handout. At the end of the unit design teams will come back together as a class to review greenhouse concepts and then identify, design, and construct a greenhouse for the classroom.

3.1.3 Activity - Setting Up Your STEAM Research Notebook and Plant Samples - 30 minutes

Following the introduction of the unit, students should spend 15 minutes working on setting up their STEAM Research Notebook and recording their first notebook entry. The teacher should distribute and review the Example Title Page and Example Table of Contents handout and review these with the students as well as the Notebook Tips and Notebook Grading Rubric handouts. Students should paste or tape the Unit Challenge Description, Notebook Tips, and Notebook Grading Rubric into their STEAM Research Notebooks following the Table of Contents. For their first notebook entry students should think and write about the following questions:

- What are your favorite fruits and vegetables?
- What fruits and vegetables are common/uncommon around the area where you live?
- What makes the area where you live good/bad for growing vegetables?

After students have finished setting up their STEAM Research Notebooks and completing their first notebook entry, design teams should get together to plant bean seeds for future experiments (15 minutes). Each team will need 8 plastic cups and 16 bean seeds. Design teams will work together to fill each of the cups with topsoil or garden soil, leaving 1 inch between the soil surface and the top of the cup. Soil should be moistened (but not saturated) with water. Then teams will place 2 seeds in each plastic cup. Seeds should be covered with a thin layer of soil and lightly tamped down so that the seed and soil come into contact. Note that the bean seeds should NOT be buried deeper than 1 inch. Once the seeds have been placed into the plastic cup, place a layer of clear saran wrap on top. Seeded plastic cups can be placed by a window where they will receive natural sunlight, or lamps may be used to supply light to the seeds.

3.1.4 Deliverables for Session One

At the end of this session, students should have completed the following:

- Each student should have set up their STEAM Research Notebook and logged their first entry
- Each design team should have 8 plastic cups containing 2 bean seeds each.

3.1.5 SESSION ONE RESOURCES

Example Title Page

Example Table of Contents

Unit Challenge Description

Engineering Design Process

Types of Greenhouses

Notebook Tips

Notebook Grading Rubric

Example Title Page

Classroom Greenhouse Design

Notebook Owner: Francis Farmer

Team Members: John Doe, Jane Doe, Francis Farmer, Tom Ato, Jenny Appleseed

Teacher: Mrs. Smith

Example Table of Contents

Date	Activity	Page Number
Aug. 16, 2018	Setup research notebook and write thoughts on fruits and veggies.	1-2

Unit Challenge Description

Fruits and vegetables are a necessary part of a healthy diet. In fact, based on Chinese dietary guidelines, fruits and vegetables should make up nearly 1/3rd of our daily food intake. However, fresh fruits and vegetables can often be limited in certain areas where soils, climate, and accessibility can increase costs to both producers (to grow fruits and vegetables) and/or consumers (to buy fruits and vegetables. One method which is being promoted to overcome some of these obstacles is called controlled-environment agriculture, or CEA. CEA relies on the use of greenhouses and other infrastructure to provide optimal growing conditions for plants such as fruits and vegetables allowing them to be grown virtually anywhere in the world and in the most efficient and environmentally-conscience way possible.

You will work in teams to act as companies that have been asked to create a greenhouse that can provide fresh fruits and vegetables to the school cafeteria and that will also serve as a learning laboratory and model for controlled environment agriculture (CEA) for the community. You will need to design and build your greenhouse within material and budgetary constraints.

Unit Tasks and Activities:

1. Student teams will explore the interaction between human-controlled and natural systems in regard to how food is grown and distributed. Students create their own "plates" of food and discuss the costs and consequences of growing food. (Session Two)
2. Teams will research and learn about the natural systems and cycles that support plant growth. Students will learn about the cycling of water, energy, carbon, and nutrients, as well as explore agroecosystems and what services they provide. Teams will conduct experiments using bean plants to manipulate various aspects of plant environments. (Sessions Three - Five)
3. Students will expand on the previous sessions to look more specifically at how crops interact with soils and climate. Student teams will take measurements from the plant experiments and conduct an analytical review of past weather events that impacted crop growth in China. (Session Six - Seven)

4. Students will explore different types of CEA systems, such as greenhouses and hydroponics. (Sessions Eight - Nine).
5. Students, working individually and in design teams will design, construct, and test a greenhouse prototype and present it to the class. (Sessions Ten - Seventeen)
6. Following peer-review, design teams come together as a class to reflect on the unit sessions and activities. The class will divide into two working groups. One group will work on developing a plan to integrate and automate the watering of each of the greenhouse prototypes. Another group will develop a Crop Management Plan to take advantage of each greenhouse prototype designs and maximize classroom production. (Session Eighteen).

Figure 3.1.1:Engineering Design Process Chart

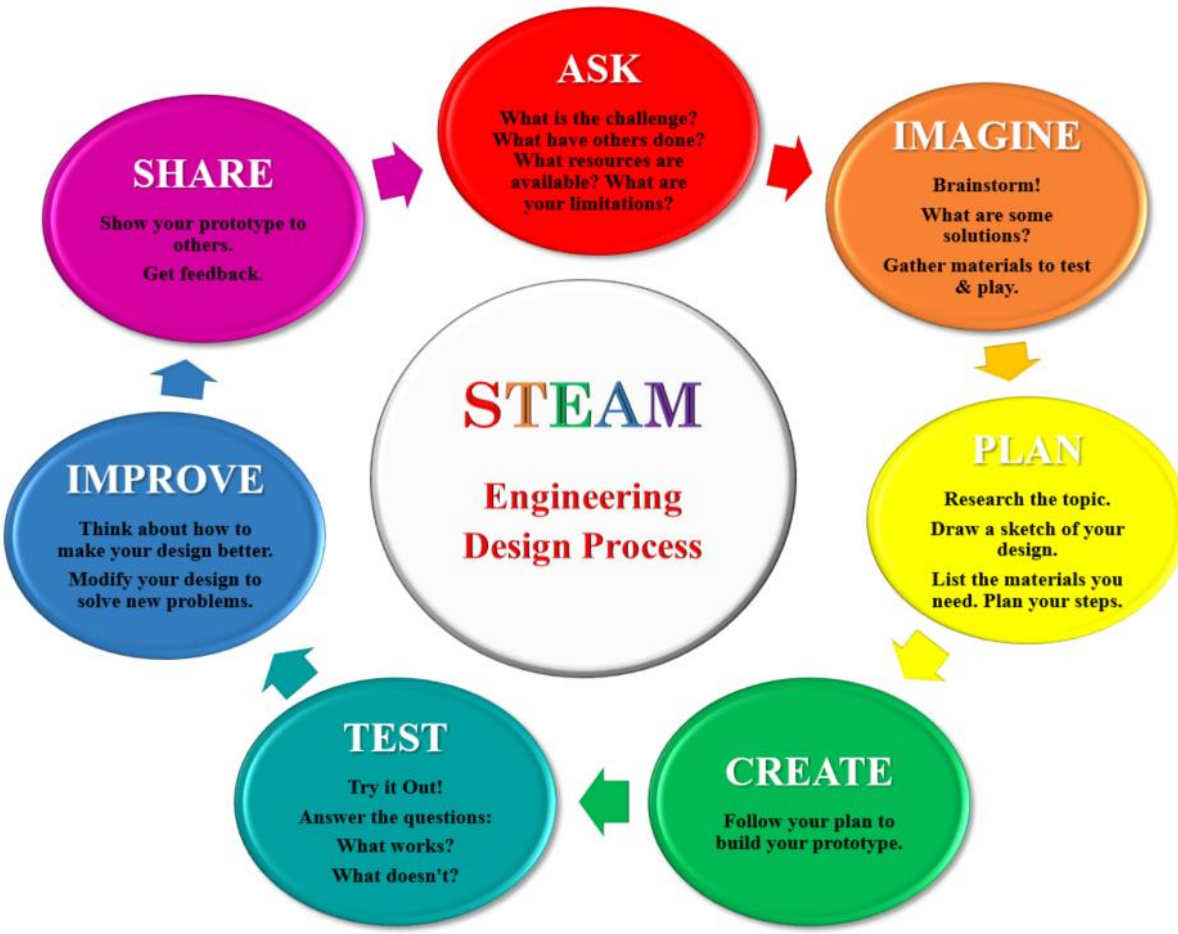


Figure 3.1.2: Types of Freestanding Greenhouses (suggested image)

Source: [University of Georgia Extension,](http://extension.uga.edu/publications/detail.html?number=B910&title=Hobby%20Greenhouses)

[http://extension.uga.edu/publications/detail.html?number=B910&title=Hobby%20Greenhouses)](http://extension.uga.edu/publications/detail.html?number=B910&title=Hobby%20Greenhouses)

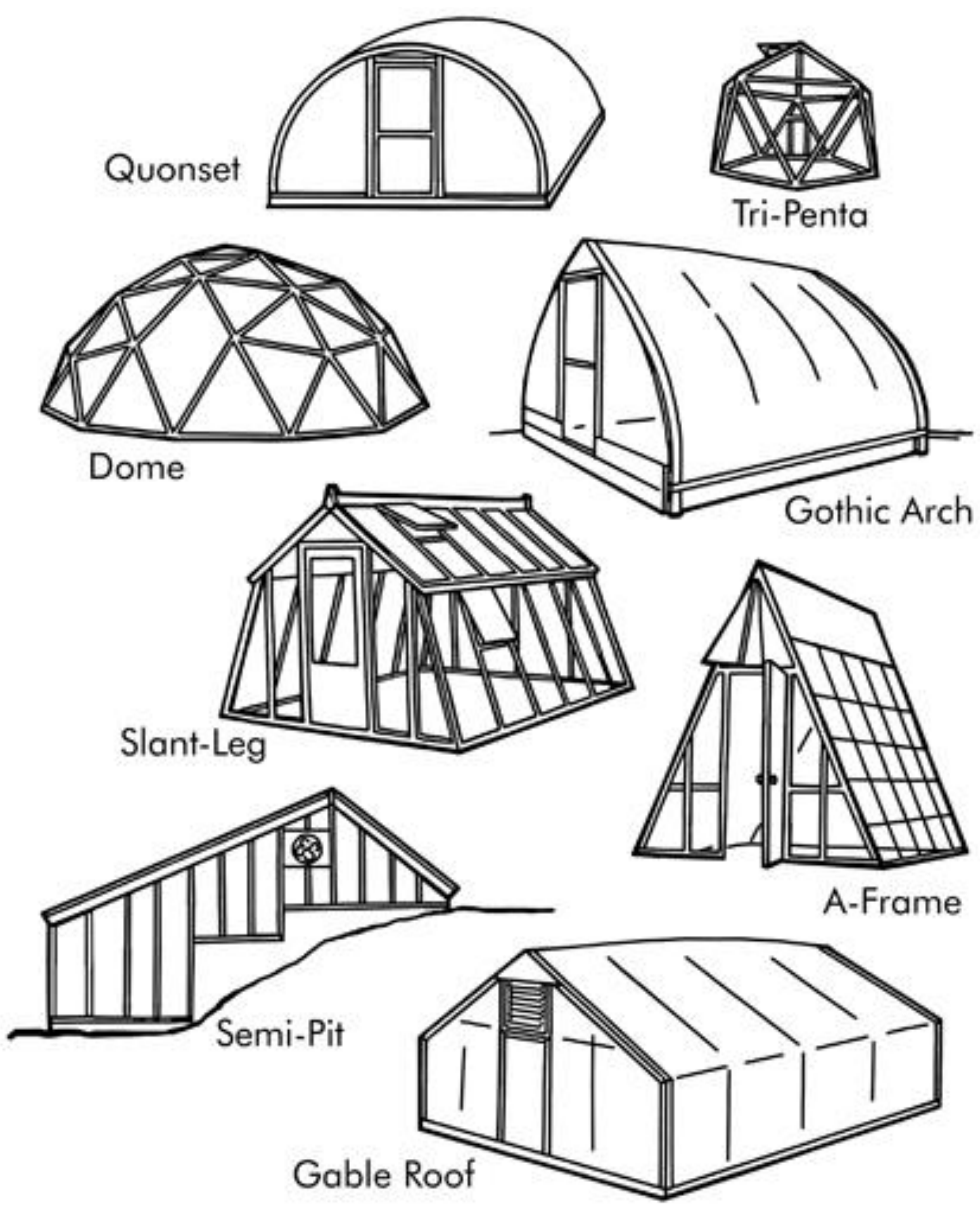
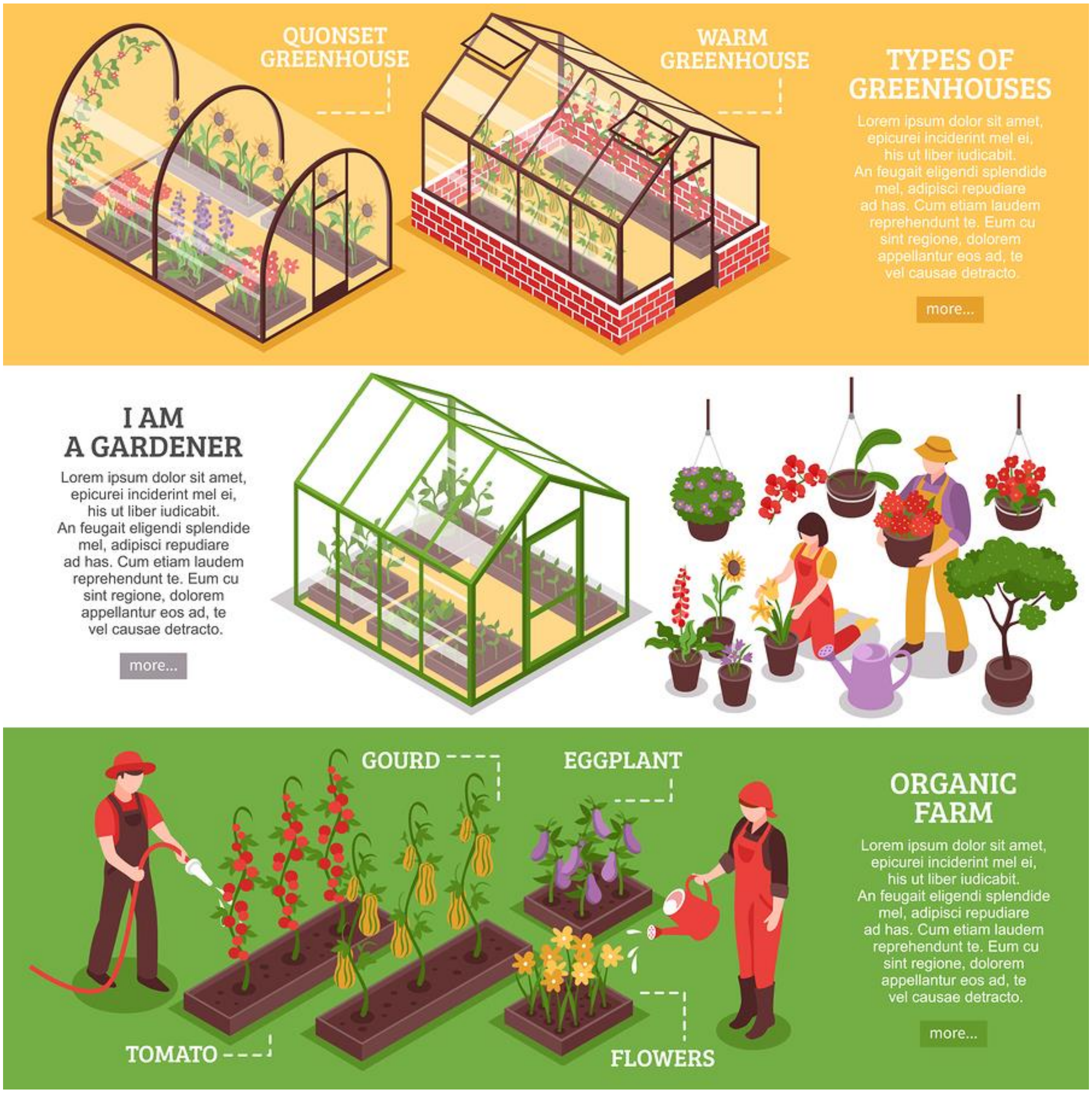


Figure 3.1.3: Types of Greenhouses



Notebook Tips

Research notebooks are a critical tool for engineers, researchers, and designers to help document and evaluate results from their work. Your notebook will be used throughout this unit to compile information and record results from session activities, brainstorm ideas, and think about various aspects of your greenhouse prototype design. The following tips will be useful in developing your STEAM Research Notebook.

- At the start of any new project you should include a Title Page which lists a brief but descriptive name for the project, yourself, and any other team members involved in the project.
- Following the Title Page, you should leave at least 1-2 blank pages to begin a Table of Contents. This should include the date of any new notebook entry, a brief but descriptive title for the day's activity, and page numbers that cover any of the pages or materials used.
- Handouts or other session materials should be taped or glued into your STEAM Research Notebook.
- Every page should be numbered and have a corresponding entry in the Table of Contents.
- You are encouraged to include sketches, coloring, or other types of expressions that may help convey information and detail about your daily activities.
- You should NOT erase or remove any notes, thoughts, sketches, pages, or any other information from the notebook. You may include a single strikethrough. It is expected that these notebooks will evolve and change over time. In order to understand this evolution in thoughts and ideas it is critical that you can see prior information, even if it is old or has been replaced.

Notebook Grading Rubric

STEAM Research Notebook Rubric **Name** ________________________ **Score** __________ This is what will be used when scoring your notebook.	
4 points	★ All pages are numbered with titles and dates included. ★ The Table of Contents is up-to-date. ★ ALL notes, labs, activities, and vocabulary entries are complete. ★ High quality reflections are included for each activity. ★ It is neat and accurate with lots of detail. Colors and labels are always added. ★ Real-world connections are added to many notes.
3 points	★ MOST of the pages are numbered with titles and dates included. ★ The Table of Contents is up-to-date. ★ MOST required notes, labs, activities, and vocabulary activities are complete. ★ Reflections are included for each activity. ★ Neat and accurate with some detail. Color and labels are usually added. ★ Some real-world connections are added in the notes.
2 points	★ Pages are numbered and many have titles and dates. ★ The Table of Contents is not complete. ★ SOME required notes, labs, activities, and vocabulary activities are missing. ★ Reflections lack thought and effort. ★ Effort to be neat and most work is accurate with basic content. Some color and labels. ★ 1-2 real-world connections are added in the notes.
1 points	★ Missing page numbers, titles, and dates. ★ Missing many Table of Contents entries. ★ Few required notes, labs, activities, and vocabulary activities are complete. ★ Few reflections are written about activities. ★ Little effort made for neatness. Several errors found in content. Lacks detail or color. ★ No real-world connections are added.

Notebook Grading Rubric (continued)

Rubric for Writing					
Name ________________________			Date ____________________		
	4	3	2	1	Score
Topic	I always stick to the topic.	I mostly stick to the topic	Sometimes I writing wander to a different topic.	I didn't stick to the main topic.	
Details	I added many extra details.	I added some extra details.	I added a few extra details.	I didn't add any details.	
Stories	If this is a story: It has a beginning, middle, and ending.	If this is a story: It has a beginning and ending.	If this is a story: It has a beginning and middle.	If this is a story: It doesn't have a beginning middle, or ending.	
Words	I used our key science words and other interesting words correctly.	I used the key science words correctly.	I used some key science terms, and most were used correctly.	I forgot to use our key science terms.	
Sentences	My sentences are all different.	Most of my sentences are different.	Some of my sentences are the same.	My sentences are all the same.	
Punctuation	I use punctuation on every sentence.	I almost always use punctuation.	I sometimes use punctuation.	I don't use punctuation.	
Spelling	I spelled all words correctly.	I spelled most words correctly.	I spelled some words correctly.	I didn't spell any words correctly.	

Notebook Grading Rubric (continued)

Picture Rubric		
	4	★ **Many labels and extra details are added.** ★ **Many colors have been added.** ★ **Picture is neat and clean.**
	3	★ **Most labels and extra details are added.** ★ **The picture is outlined.** ★ **Several colors have been added.** ★ **Picture is neat and clean.**
	2	★ **Some labels and extra details are added.** ★ **The picture is outlined.** ★ **Two colors have been used.** ★ **Picture is neat.**
	1	★ **One detail has been added.** ★ **Picture is not outlined.** ★ **No color has been added.** ★ **Picture is not neat or clean.**

3.2 SESSION TWO - Exploring Coupled Human and Natural Systems through Agriculture - 40 minutes

In Session Two, students will begin to explore how natural and human systems are inextricably linked through agriculture production, and discuss how certain human-mediated actions can have positive or negative consequences on natural and human systems (including ecosystem degradation, climate change, and famine). Students will be exposed to different types of agricultural production methods used across human history to feed people including greenhouse systems (e.g. controlled-environmental agriculture, sustainable agriculture, etc.). The concepts of sustainable agriculture, food mapping, and environmental resources will be introduced. The activity is designed to help students become familiar with the demands placed on both human and natural systems and how those systems interact to feed a growing population.

3.2.1 Teacher Preparation, Session 2

The teacher should assemble materials, duplicate handouts, and preview videos used in the session. The video provides the major concepts regarding human history with natural resources and food; however, additional familiarity with local community history related to agriculture would enrich the students learning. Preview the mapping activity described. Preparing a list of common foods in your students' diets as well as where those foods are grown could ahead of time could help the teacher demonstrate mapping examples. Use a computer mapping application (such as Google Maps) if available, and check to make sure all mapping devices are prepared to map for the day's lesson. If using a standard 2-dimensional map and ruler, make sure map has major world landmark references as well as a key and legend for measuring distances. The teacher should review the calculation of the statistical measures that will be used by students by accessing the Khan Academy resources provided in the Digital Resources list below.

The teacher should ensure students tend bean seeds, and make observations of their bean plant cups in their STEAM Research Notebook.

Digital resources:

Video: Human Prehistory 101 (7 minutes) -

https://www.tes.com/lessons/FtLDUNyioDeJZw/early-agriculture

The evolution of agriculture graphic -

https://primalgroup.com/wp-content/uploads/2016/11/The-evolution-of-Agriculture-timeline_24-June16.jpg

World Map or Computer Mapping Application (e.g. equivalent to Google Maps)

Mean, median, mode review – Khan Academy –

https://www.khanacademy.org/math/statistics-probability/summarizing-quantitative-data/mean-median-basics/a/mean-median-and-mode-review

Internet access (Optional)

Student Materials:

STEAM Research Notebook

Pen or Pencils (single or multiple colors)

Ruler (if printed map is used)

For MyPlate art (various options):

Multimedia print (magazines, advertisement flyers, etc.)

Glue (or other adhesive)

Colored Pencils

Water-color paints

Construction Paper

Handouts:

The Evolution of Agriculture Graphic (suggested image)

MyPlate Student Sheet

Table 3.2 Explicit Knowledge for Session Two

Core Area	Knowledge Required	Supports for Student Learning
Science	Students should understand human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space, but individuals and communities are doing things to help protect Earth's resources and environments	The teacher will obtain, combine, and share information about ways individual communities use science ideas to protect the Earth's resources and environment. The teacher will provide background information and guidance with high quality support materials, including example products, teacher instruction, and online videos and/or tutorials.
Mathematics	Students should be able to make linear measurements and estimations.	Teacher can provide guidance by demonstrating examples in class and providing opportunities for students to practice.
	Students should be able to calculate the mean, median, and mode of a given sample and use these statistical measurments to compare with other sample data.	
Language Arts	Students should be able to write narrative text about their experiences using effective technique, descriptive details, and clear event sequences. Students should understand the value of reflection and the habit of summing up their learning.	A writing rubric is included in the STEAM Research Notebook for students to use to self-assess their writing. The teacher will provide models of explanatory writing and science notebooks using books illustrating science notebooks such as the one recommended in Session 1.
Art	Students should be able to produce artistic products that demonstrate consideration of elements of line, color, shape, texture, impasto, and orientation (landscape and portrait). Students will apply knowledge of art as they construct their ideal meal plate.	The teacher will provide feedback on student team choice of artistic representations.

3.2.2 Introduction – 10 minutes

Begin Session Two by reminding students of the challenge for the unit. Start by displaying the Unit Challenge. Next, give student teams five minutes to discuss the question "where did my lunch come from?" and then ask them to share their ideas with the class. Record the main ideas in a list on the board. Allow about five minutes for team discussions and five minutes for sharing ideas.

3.2.3 Activity - Evolution of Agriculture and Food Mapping the Ideal Meal Background – 25 minutes

This activity is designed for students will begin to build their background knowledge about coupled human and natural systems. This will lead to an understanding of the challenges of feeding a growing population with a nutritious, fresh diet and provide background for students as they begin to prepare for designing their greenhouse prototype later in the unit. How people produce food impacts human and natural systems by polluting the atmosphere, depleting natural resources, and contributing to the deterioration of global health. New agricultural technologies are needed to help people ensure a safer, more productive and sustainable environment for future generations. The teacher should explain that students will be using statistical measures to evaluate characteristics of where their food comes from. These are the mean (or average), median (or central location of data), and mode (most frequently occuring value).

Procedures for Evolution of Agriculture and Food Mapping Activity

1. Share with students a brief history of interactions between humans and the environment through agriculture across the world. Show the video https://www.tes.com/lessons/FtLDUNyioDeJZw/early-agriculture
2. Discuss with students the overview of The Evolution of Agriculture graphic. Have students provide of examples of how these different methods help produce food for people and impact the environment.
3. Have students design their ideal food plate or meal (e.g. breakfast, lunch, or dinner) on the student MyPlate Sheet.
    a. This is meant to be an artistic expression that can use various forms of art.

i. Students can use collage by gathering images from magazines or other printed materials to cut out food items to glue on their plate.

ii. Students can use colored pencils to draw realistic sketches of food images, or watercolor paints to paint their food on the plate

iii. Students can use more abstract art forms such as color-blocking mosaic. Using various colors of construction paper cut into cubes and adhesive, students can glue together colorful blocks that abstractly represent their food plate.

4. Now have students calculate how far their ideal food plate or meal travels to get to them. Start by putting up a world map on the wall (using a projector), and marking your classroom location on it. To incorporate technology, have students use a computer mapping application that measures distance. One by one, have students map their food labeling each food item (e.g. almonds) and its location on the map (e.g. California).
5. Using a map application, have students measure the distance from their food source to their home or classroom. Have students calculate the mean, median, and mode of the distances for all their food sources and have students share their results with the team. Have teams report their group's results to the whole classroom and discuss. Which foods traveled the shortest distance? Which foods traveled the farthest? Which foods required the most energy (e.g. fossil fuels) to get to students' plates? The least amount of energy?

Optional: Ask students to list all the different types of food that are produced within 100 km of their school and list how those foods are produced (garden, farm, factory, etc.).

3.2.4 STEAM Research Notebook Entry – 5 minutes

Have students respond to the following in their STEAM Research Notebooks: Reflect on your experience mapping where your food comes from. What are some of the food origins you found most interesting? Least interesting? How might the food you eat impact the environment? What are some benefits to the environment for growing fresh, local food for your school cafeteria? What are your initial thoughts about what kinds of food you might want to grow in your classroom greenhouse?

Have students water bean seeds, and make observations on their bean plant experiments in their STEAM Research Notebook.

3.2.5 Deliverables for Session Two

At the end of the session, students should have completed the following:

- Entry in STEAM Research Notebook
- MyPlate Student Sheet
- Food Mapping Activity

3.2.6 SESSION TWO RESOURCES

The Evolution of Agriculture Graphic
MyPlate Student Sheet

Figure 3.2.1: The Evolution of Agriculture Graphic (suggested image)

(Source: Primal Group (2016)- https://primalgroup.com/wp-content/uploads/2016/11/The-evolution-of-Agriculture-timeline_24-June16.jpg

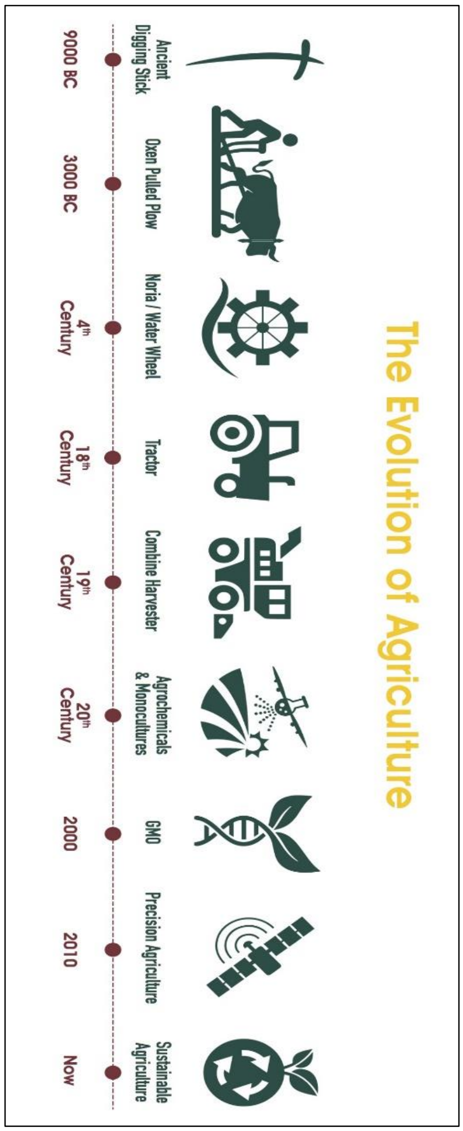
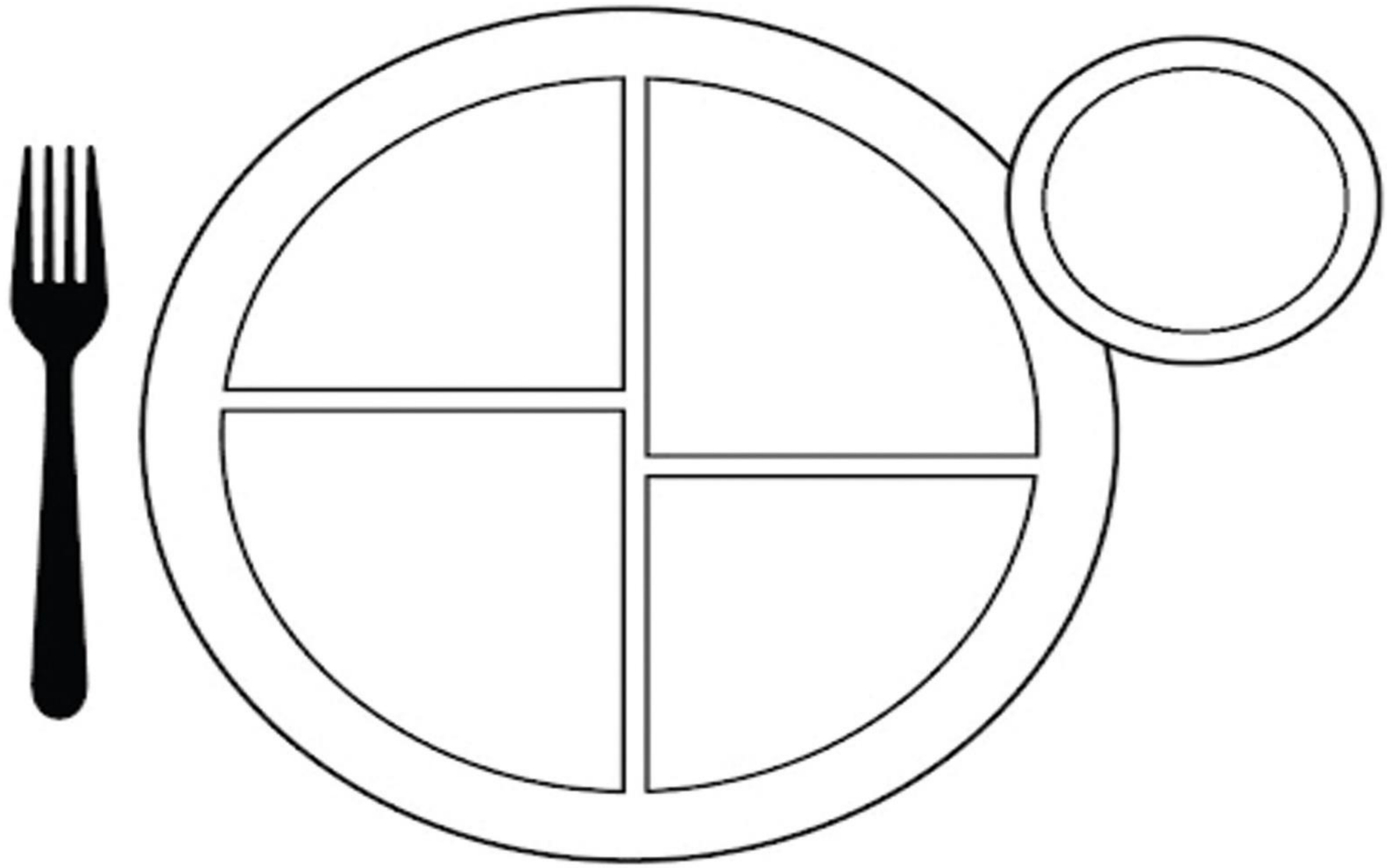

The Evolution of Agriculture
Ancient Digging Stick
9000 BC
Oxen Pulled Plow
3000 BC
Noria / Water Wheel
4th Century
Tractor
18th Century
Combine Harvester
19th Century
Agrochemicals & Monocultures
20th Century
GMO
2000
Precision Agriculture
2010
Sustainable Agriculture
Now

Figure 3.2.2: MyPlate Student Sheet

Source: www.choosemyplate.gov



3.3 SESSION THREE - Water and Energy Cycles - 40 minutes

In Session Three students will learn about how water and energy moves through various landscapes and how crops and people interact with these cycles through processes such as photosynthesis, solar energy, and hydropower. Students will work in their design teams to set up an experiment that will manipulate light conditions for growing plants and complete hypotheses in their STEAM Research Notebooks regarding anticipated results. Future activities will include measuring and charting the results of the experiment over time as a class.

3.3.1 Teacher Preparation, Session 3

The teachers should assemble materials, duplicate handouts, and preview videos used in the session. Much of Session Three will quickly review prior students knowledge on the key concepts of the water cycle and photosynthesis. The teacher should be prepared to facilitate a quickly paced review to ensure students have adequate time to setup their bean plant growth chambers that will be used for experimentation over the next several sessions through Session Nine. The teacher should ensure students tend bean seeds, and make observations on their bean plant experiments in their STEAM Research Notebook. A short review on calculating the surface area and volume of cup is can be accessed through the YouTube video link provided under Digital Resources.

Digital Resources:

Lateral Area, Total Area, and Volume of a Coffee Cup –

https://youtu.be/hu7hmiIR2aQ

Student Materials:

STEAM Research Notebook

Pen or Pencils (single or multiple colors)

Colored Pencils

Other Materials (1 for each design team):

Measuring Cup or Graduated Cylinder

Weighing Scale (sub-gram accuracy)

Soil Thermometer

16 oz. plastic cups; Clear (3/design team)

Multipurpose sealing wrap

Tin foil

Tape

Water

Ruler

Hole punch

Handouts:

Water Cycle

Forms of Energy

Photosynthesis

Light Chamber Experiment

Table 3.3 Explicit Knowledge Required for Session Three

Core Area	Knowledge Required	Supports for Student Learning
Science	Students should understand that a system can be described in terms of its components and their interactions.	Teacher will use models to describe how energy, water, carbon, and nutrients move through the environment.
	Students should understand that plants acquire their material for growth chiefly from air, sunlight,and water. The water cycle and photosynthesis should be a review to students.	The teacher will provide background knowledge and examples about controlling factors in plant growth, biogeochemical cycling, and CEA systems
Mathematics	Students should be able to write and interpret numerical expressions.	The teacher will provide support to student teams as they make measurements and calculations in the Light Chamber Experiment.
	Students should be able to use	

	variables to represent numbers and write expressions when solving a real-world or mathematical problem	
	Students should be able to solve simple questions about decimal places and percentages.	
	Students should be able to recognize a statistical question as one that anticipates variability in the data related to the question.	
	Students should be able to calculate the area and volume of circles, triangles, and polygons.	
Language Arts	Students should use communication skills including letters, words, and sentences to communicate their ideas.	Teachers will support students to articulate their ideas.
Art	Students should use colored pencils to sketch realworld observations and dimensions	Teacher will provide students feedback on colored sketches.

3.3.2 Introduction - 10 minutes

The teacher will inform the students that the next 3 sessions will focus on the environment around us. More specifically, the class will discuss how water, energy, carbon, and nutrients move through the environment and what services agriculturally-based environments, or agroecosystems, provide us. Students should first be familiar with the water cycle as well as photosynthesis. The teacher should faciliate a review discussion on how water moves and flows through the landscape and what factors drive this movement. At the end of this discussion the students should understand that water moves between air (water vapor, clouds, etc.) and land (surface and subsurface water). The cycling between these two different physical states is driven by solar energy.

Next students should be given the Forms of Energy handout. Again, the teacher should ask a few questions and lead a classroom discussion on the energy cycle. What types of energy can students think of (e.g. wind, solar, hydropower, nuclear, etc.)? How is this energy generated? How is this energy stored? For example, hydropower is produced when water is moved from a higher elevation to a lower elevation. As the water moves from high to low, the force of the water drives large turbines which generate energy that is stored in batteries or transported to an energy storage station.

The teacher should handout the Photosynthesis handout. The teacher should begin to point out that the most basic form of energy, light energy, comes directly from the sun (solar energy). Plants are unique in that they able to capture this energy directly and use it along with air and water to generate energy. This process is called photosynthesis and this specific cycling of energy is critical to producing food for all other animals, including humans, that consume plant material.

3.3.3 Activity - Light Chamber Experiment - 25 minutes

Students should get into their design teams and get 4 of the 8 plastic cups that they seeded with plants during Session One. The teacher should explain that each of these cups represent a sample and that during the next 2 sessions they will be experimenting with these samples to see how changing growing conditions (i.e. treatments) can affect how plants grow. These different conditions can begin to give students an idea about how greenhouses can be developed to control plant growth by measuring how each of these samples respond to the treatments. In research this is referred to as the variation and explains by how much a certain treatment can change a condition and what the range of expected values might be. During this activity students will construct different lids that can be attached to the seeded plastic cups in order to vary the amount of light that is able to reach the plants.

The teacher should give each design group the Light Chamber Experiment handout. This handout includes instructions on how to construct 3 different light chamber lids and label each sample. Each chamber is designed to allow different amounts of light in to the plant. The fourth and final treatment will be an uncovered sample. Prior to placing the light chamber lids on the plastic cups students should weigh and take soil temperature measurements from each of the plastic cups. After weighing each cup and recording the weight and temperature in their STEAM Research Notebook, students should use the measuring cup or graduated cylinder to add water to the plastic cup. Again, the goal is to have the soil inside the cup moist but not fully saturated. The amount of water added to each cup should be recorded in the students' STEAM Research Notebooks. Students should then weigh each of the plastic cups again and record the weight of each in their STEAM Research Notebooks. The difference in weight before and after water is added to the seed plastic cups reflects the weight of the water added. Finally, the students should place the constructed light chamber lids on top of the seeded plastic cups. Lids can be fastened or secured using tape.

At the end of the activity session each design team should report to the class the weight and temperature of each of the 4 plastic cups used in this activity. The teacher should graph the results from each of the design teams on a chart that is displayed in the classroom. In future sessions design teams will re-weigh the samples from each treatment to evaluate the change in weight and temperature and theorize/discuss what changes occurred if any to cause this change. At the conclusion of these future activities, new graphs will be made from the design team results and used to compare against the original classroom graph.

3.3.4 STEAM Research Notebook Entry - 5 minutes

Each student should spend the final 5 minutes of the session completing a STEAM Research Notebook entry on water and energy cycles. Students should focus on writing down key points from the discussion, any remaining questions they have following the discussion on water and energy cycles, and hypotheses they have regarding which treatments will change, either in weight or temperature, over time and what is causing this change. Students should sketch the image of experimental setup for the Light Chamber Experiment.

3.3.5 Deliverables for Session Three

At the end of this session the students will have completed the following:

- Constructed light chambers representing 4 different treatments and placed a sample in each treatment

- Recorded the experimental design and initial weight/water measurements in their STEAM Research Notebook
- Completed their STEAM Research Notebook entry for the session

3.3.6 SESSION THREE RESOURCES

Water Cycle

Energy Cycle

Photosynthesis

Light Chamber Experiment

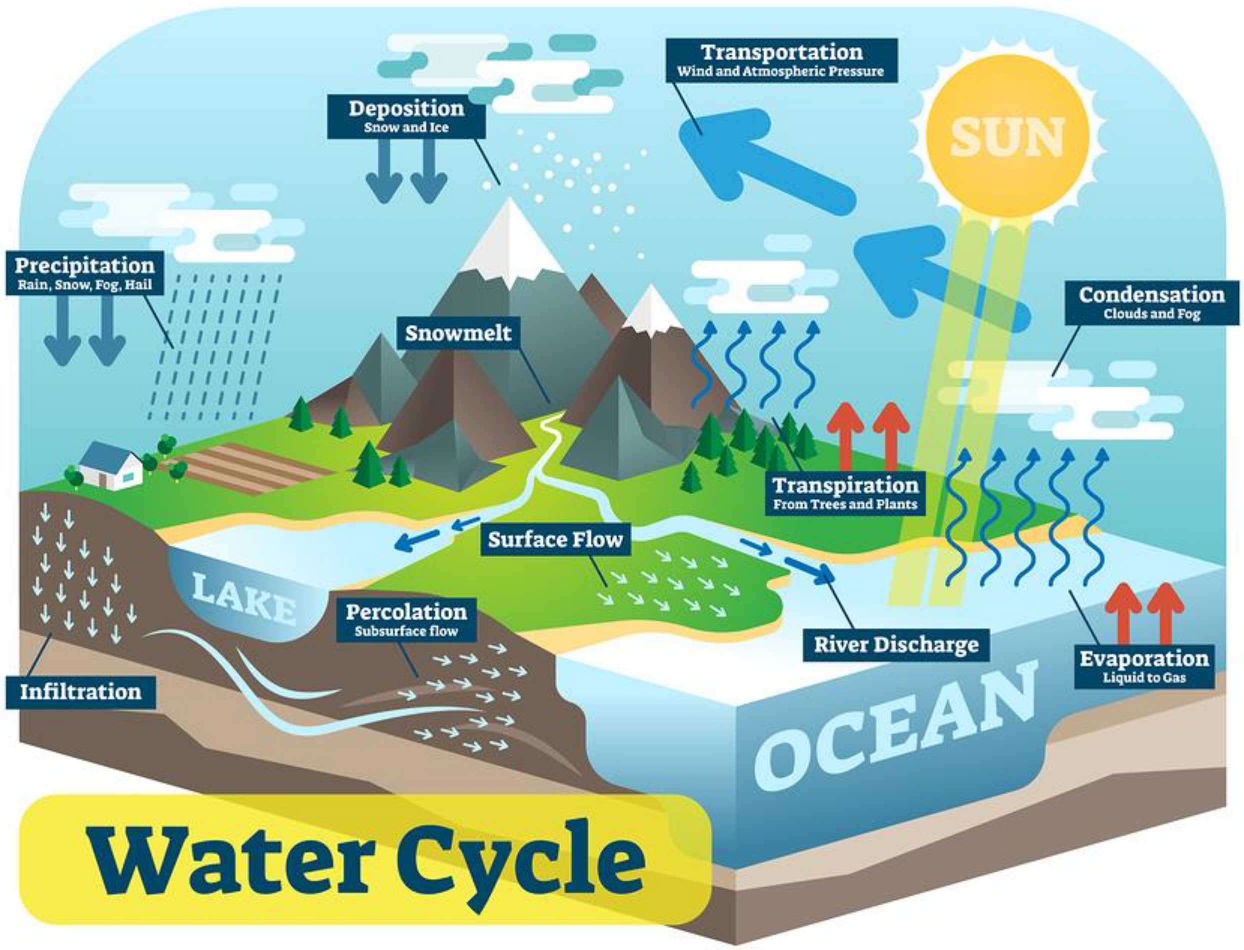
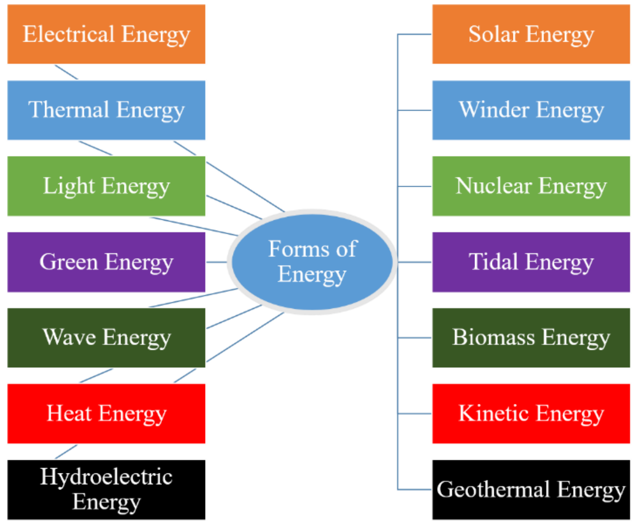


Image retrieved from: https://www.bigstockphoto.com/image-222588433/stock-vector-water-cycle-graphic-scheme%2C-vector-isometric-illustration-with-water-bodies-and-geological-relief

Figure 3.3.2: Forms of Energy



https://byjus.com/physics/energy/

Figure 3.3.3: Photosynthesis

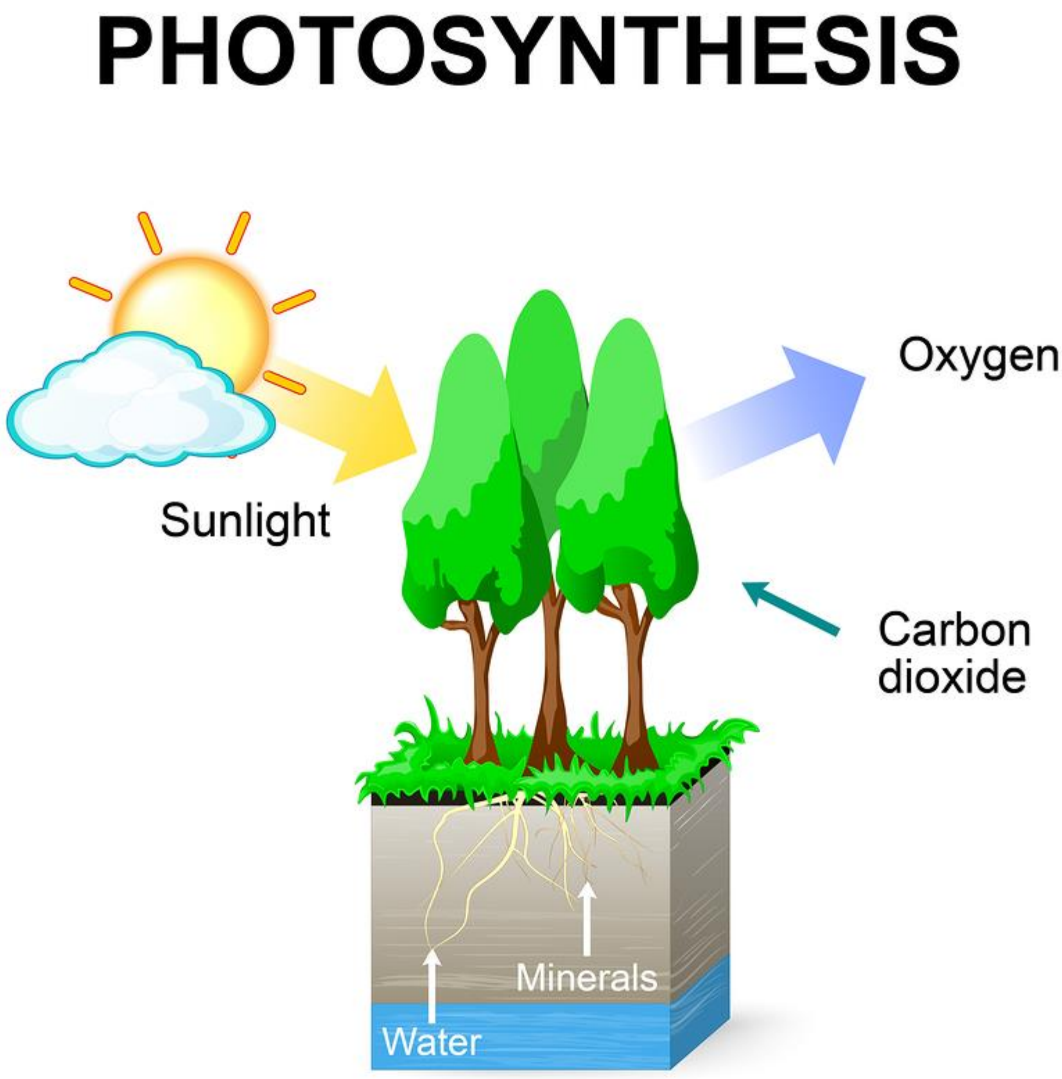


Image retrieved from: https://www.bigstockphoto.com/image-144820283/stock-vector-photosynthesis-vector-schematic-of-photosynthesis-in-plants

Light Chamber Experiment

Today we discussed how water and energy are cycled through natural systems and how these cycles support plant growth and the production of food. In this experiment we will construct 4 different light chambers that will influence the amount of light received by our growing bean plants. A listing of each treatment is included in Table 1.

Table 1.

Treatment	**Code**
No Chamber	N
Clear Chamber	C
Semi-clear Chamber	SC
Shaded Chamber	SH

The materials needed by each design team for this experiment include:

- Measuring Cup or Graduated Cylinder
- Weighing Scale
- Clear plastic cups (3 total)
- Multipurpose sealing wrap
- Soil Thermometer
- Tin foil
- Tape
- Water
- Hole punch
- Ruler
- STEAM Research Notebook and pencil

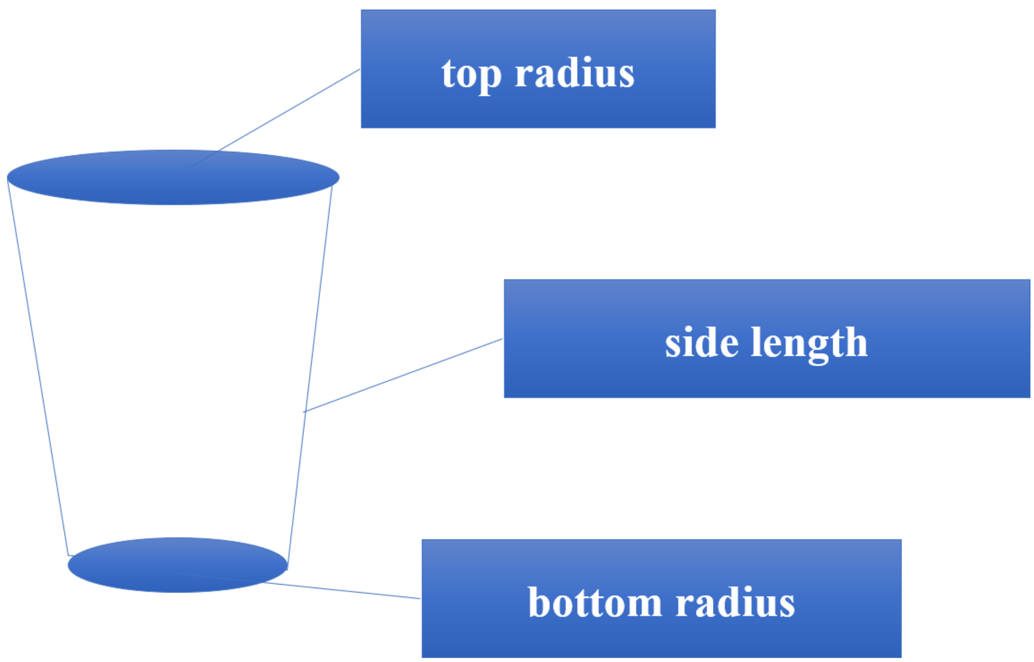
Steps

1. Design Teams should start out by labeling each of the seeded plastic cups with the appropriate treatment code. This experimental design and coding system should also be recorded in each students' STEAM Research Notebook.

2. Next, design teams should construct their light chambers using the cups, parchment paper, and tin foil. Tape can be used to cover cups in each parchment paper or tin foil to manipulate how much light will be able to get through to the plant. The lateral surface area (LSA) of a cup is given by the equation (see Figure 3.3.4: Cup Dimensions):

$$LSA = \pi(radius_{top} + radius_{bottom})\ side\ lengthof\ cup$$

Figure 3.3.4: Cup Dimensions



Students should estimate the total percent of the lateral surface area that is covered in the tin foil treatment by dividing the total LSA by the remaining LSA that is not covered by tin foil. At the end of this step design teams should have 1 clear cup, 1 cup covered in parchment paper representing the semi-clear chamber (SC), and 1 cup with the majority of its surface covered in tin foil representing the shaded chamber (SH) as shown in Figure 3.3.5. Note that design teams should make sure that at least some light can enter the shaded chamber. Also, oxygen needs to be able to enter the chamber so design teams should use a hole punch to make a series of holes around the rim of the chamber.

Figure 3.3.5: Light Experiment Cups. Plastic cup without covering, with parchment paper covering, and with tin foil covering.

Light Chamber Experiment (continued)

3. Before placing the light chambers on top of the plant cups, design teams should weigh and record the plant cups.
4. Use the soil thermometer to measure the soil temperature of the cup. Insert the end of the thermometer 2-4 centimeters into the soil when taking your measurement. Record this in your STEAM Research Notebook.
5. Next students should add 100-125 mL of water to the plant cups. Plant cups should be re-weighed at this point and entered again into the STEAM Research Notebook.
6. Subtract the first weight from the second weight to determine the total weight of water added to each plant cup. Students should write an equation using letters to conceptualize this calculation. This should include a description of each letter used as well as the appropriate units.
7. Finally, attach each of the light chambers onto the plant cups using tape (Figure 3.3.6.)

   Figure 3.3.6. Plastic cup growing chamber.

3.4 SESSION FOUR - Nitrogen, Phosphorus, and Carbon Cycles - 40 minutes

Session Four will expand on water and energy cycles to introduce students to the cycling of nutrients and carbon, the building blocks of natural systems that support plant growth and productivity. Students will work in their design teams to set up an experiment that will manipulate nutrient supplies for growing plants and complete hypotheses in their STEAM Research Notebooks regarding anticipated results. Future activities will include measuring and charting the results of the experiment over time as a class.

3.4.1 Teacher Preparation, Session 4

Teachers should assemble materials, duplicate handouts, and preview videos used in the session.

The teacher should informally assess general student understanding of plant's needs for growth, and identify if additional support is needed for basic comprehension that Nitrogen, Phosphorus, and Carbon impact plant growth. The goal for the Unit Challenge is for the students to build a greenhouse and know that these nutrient factors are variables that exist and can be changed and managed in a greenhouse to optimize plant growth. Additional Supplemental Sessions 1-3 in Appendix A has been provided to build more comprehensive understanding of the Nitrogen, Phosphorous, and Carbon Cycles. The teacher should ensure students tend bean seeds, and make observations on their bean plant experiments in their STEAM Research Notebook. The bean plant observations will take time and will last through Session 9.

Student Materials:

STEAM Research Notebook

Pen or Pencils (single or multiple colors)

Other Materials:

Elemental fertilizer (e.g. Miracle-Gro All Purpose Food, 1lb)

Organic fertilizer (e.g. Fish-based Plant Fertilizer, 32oz)

For each design team:

Measuring cup or Graduated cylinder

Mixing cup

Weighing scale

Soil Thermometer

Measuring spoons, ¼ tsp. And 1 tsp.

Calculator

Handouts:

Nitrogen Cycle

Phosphorus Cycle

Carbon Cycle

Fertilizer Experiment

Table 3.4 Explicit Knowledge Required for Session Four

Core Area	Knowledge Required	Supports for Student Learning

Science	Students should understand that energy released from food was once energy from the sun that was captured by plants in the chemical process that forms plant matter (from air and water).	Students working with their design teams will conduct water, light, and nutrient experiments to observe and measure plant growth and their material needs from natural resources.
	Students should understand that plants acquire their material for growth chiefly from air and water, and that matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment.	The teacher will provide background knowledge and examples about controlling factors in plant growth, biogeochemical cycling, and CEA systems
Mathematics	Students should be able to take brief notes on experiments and sort evidence into provided categories. Students will gather data from their light and fertilizer experiments and will discuss data with their groups and determine how changes can be accounted for.	Teachers will provide support during the sessions to make sure student teams are recording and gathering feedback from experiments and classmates.
	Students should be able to use measurement tools to make measurements and collect data; use rulers, scales, measuring cups, and thermometers to make observations about plants and growing conditions.	The teacher will provide examples of how to use measuring spoons and scales for students when necessary.
	Students should be able to calculate the mean, median, and mode of a given sample and use these statistical measurments to compare with other sample data.	Teacher can provide guidance by demonstrating examples in class and providing opportunities for students to practice.
	Display and interpret numerical data in plots and graphs	The teacher will provide support through discussion and interpretation of data.
	Students should be able to write and interpret numerical expressions.	The teacher will provide support to student teams as they make measurements and calculations.
	Students should be able to recognize a statistical question	

	as one that anticipates variability in the data related to the question.	
Language Arts	Students should be able to explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical, scientific, or technical text based on specific information in the text.	Teacher will model and provide examples of applying information from images, illustrations, experiments, and text to draw connections between concepts.

3.4.2 Introduction - 10 minutes

The teacher should start by reviewing concepts from Session Three in class discussion, asking questions such as: How is water and light cycled through natural systems? How are the two cycles linked? How do plants interact with these two cycles? Remind students that plants utilize solar energy, along with water and air, to generate energy. This energy is consumed by all kinds of animals (like humans) for production of their own energy sources, eventually passing back to natural systems where it is broken down into basic elements to be processed again by plants. This type of cycling, where energy and water cycles drive the movement of basic (chemical) elements between living (biological) organisms and the (geological) physical environment is called biogeochemical cycling. Three of the most important elements that follow these types of cycles are nitrogen, phosphorus, and carbon. Each element represents an essential building block required by all life on earth.

The teacher should distribute the Nitrogen, Phosphorus, and Carbon handouts. Begin by explaining how nitrogen is cycled through the landscape. Nitrogen in its most basic form exists as harmless N_2 gas, the most common gas in our atmosphere. Through some heavy lifting by different types of microscopic bacteria (nitrogen-fixing and nitrifying bacteria), N_2 gas is modified into different chemical forms that are available to plants and thereby support food production. Another set of bacteria come into the picture to handle excess nitrogen in the system, which can be formed through waste and decaying matter, transforming nitrate-nitrogen (NO_3) back into its atmospheric form, N_2, and completing the cycle.

The teacher should next introduce the carbon cycle. Carbon is another example of a gaseous based biogeochemical cycle, although carbon dioxide (CO_2) is present in much lower quantities in the atmosphere. Remind students that CO_2 is a key part of photosynthesis, since plants take up carbon dioxide along with sunlight and water, to produce energy. When plants are consumed this carbon is transferred to the consumer which then may pass it back to the atmosphere (through respiration, or exhaling) or back to the land during waste processes or death. At this point bacteria and fungi consume that carbon converting it back into plant-available form, or carbon is sequestered (i.e. held tightly) in soils or woody plants.

Finally, the teacher should introduce the phosphorus cycle. Unlike nitrogen and carbon, phosphorus does not have a gaseous state and is considered a sedimentary biogeochemical cycle since most phosphorus exists in a solid state, sequestered in rocks. As these rocks are weathered over time phosphorus is transported by water, wind, or other forces and deposited in soils where it can be broken down and dissolved in water and taken up by plants. Now, similar to the carbon and nitrogen cycles, consumers of plants take up this phosphorus and further utilize the resource before passing it back to the land through waste processes or death. And again, like the carbon cycle, bacteria and fungi help to recycle these wastes into plant available phosphorus, or excess phosphorus is again sequestered into rock, and the process repeats.

3.4.3 Activity - Fertilizer Experiment - 20 minutes

Students should get into their design teams and get the remaining 4 plastic cups that they seeded with plants during Session One and did not use in Session Three. The teacher should explain that each of these cups will be used as samples in a new experiment, similar to Session Three, except this time students will be experimenting with different levels of nutrients (i.e. fertilizer) to see how changing growing conditions can affect how plants grow. These different conditions can begin to give students an idea about how greenhouses can be developed to control plant growth. During this activity students will add two different types of fertilizer, one made from elemental nutrients and another made from organic nutrients, in high and low amounts and then measure changes over time in plant growth.

The teacher should give each design group the Fertilizer Experiment handout. This handout includes details on each treatment that will be part of the experiment and directions about how to calculate nutrient amounts. Students should start by labeling their plastic cups appropriately representing each treatment as well as outlining the experiment treatments in their STEAM Research Notebooks. Design teams should measure out and calculate the exact amount of each fertilizer for each treatment and mix with the specified amount of water. Students should add the fertilizer mixes to the corresponding plant cups. Next, students should weigh each cup and record the height of the bean plants in their STEAM Research Notebooks.

At the end of the activity session each design team should report to the class the weight and plant height of each of the 4 plastic cups used in this activity. The teacher should graph the results from each of the design teams on a chart that is displayed in the classroom. In future sessions design teams will re-weigh the samples and measure plant height from each treatment to evaluate the change in weight and theorize/discuss what changes occurred if any to cause this change. At the conclusion of these future activities, new graphs will be made from the design team results and used to compare against the original classroom graph.

3.4.4 Wrap-Up and STEAM Research Notebook Entry - 10 minutes

Following the setup of the Fertilizer Experiment, design teams should measure the samples from the Light Chamber Experiment and record sample weight and soil temperature (and any other visual observations) in their STEAM Research Notebooks. Recordings should include a notation of the total sample size (how many measurements have been collected) and a calculation of the mean and median. Design teams should report to the class the weight and temperature of each treatment sample and the teacher should graph results on a chart that is displayed in the classroom. If the samples appear to be drying out, students should add a small amount of water (~25-75 mL) to the sample. This water should first be weighed and notated in their STEAM Research Notebook so that students can account for this in their sample weight calculations.

Each student should spend the final 5 minutes of the session completing a STEAM Research Notebook entry on nutrient and carbon cycles. Students should focus on writing down key points from the discussion, any remaining questions they have following the discussion, and hypotheses they have regarding what affect the treatments will have on plant samples and what is causing this change.

3.4.5 Deliverables for Session Four

At the end of this session the students should have completed the following:

- Set up the Fertilizer Experiment with their design teams
- Recorded the experimental design and initial weight and plant height measurements from the Fertilizer Experiment in their STEAM Research Notebook
- Recorded measurements from the Light Chamber Experiment
- Completed their STEAM Research Notebook entry for the session

3.4.6 SESSION FOUR RESOURCES

Nitrogen Cycle

Carbon Cycle

Phosphorus Cycle

Fertilizer Experiment

Figure 3.4.1: Nitrogen Cycle

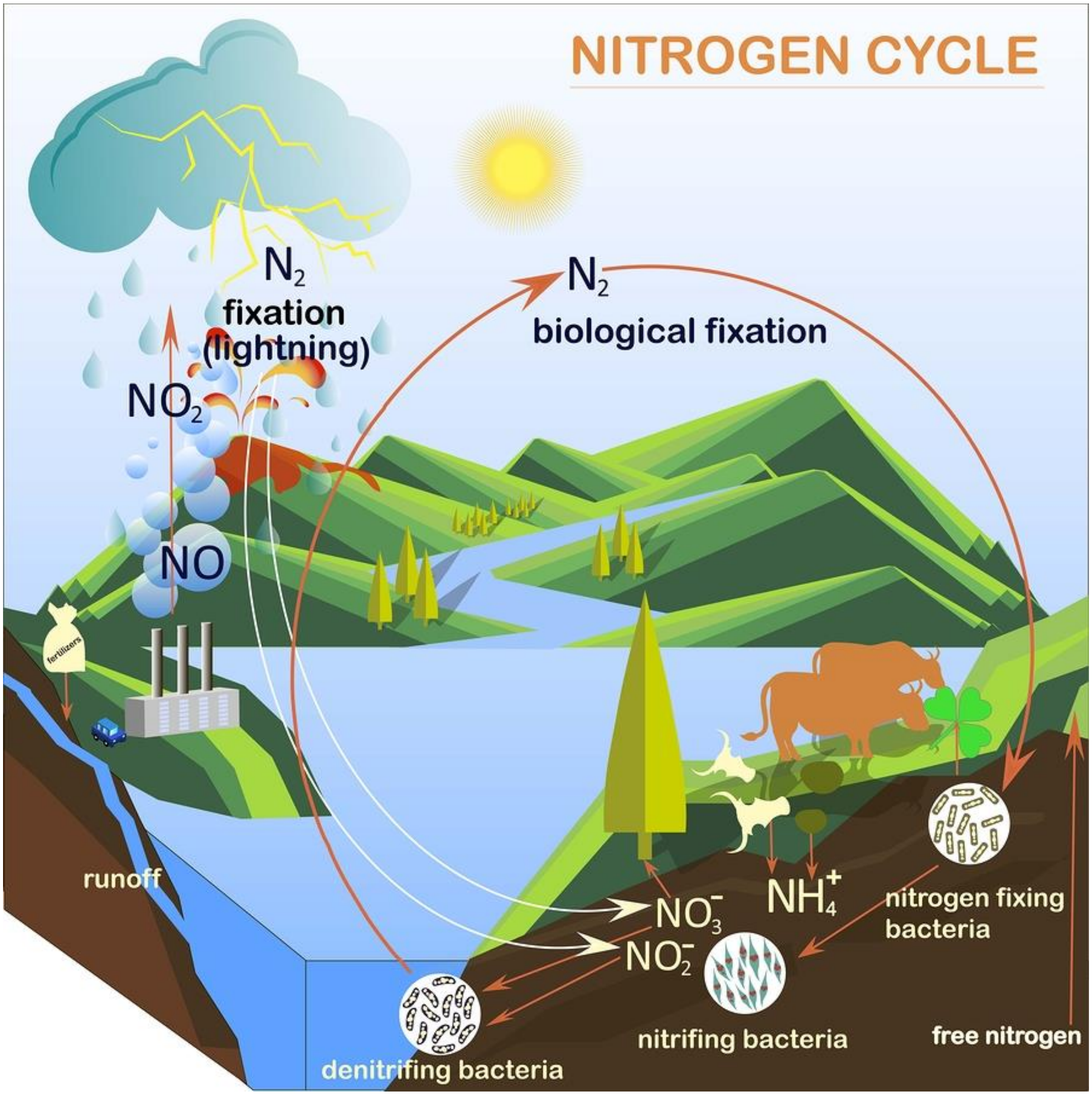


Figure 3.4.2: Carbon Cycle

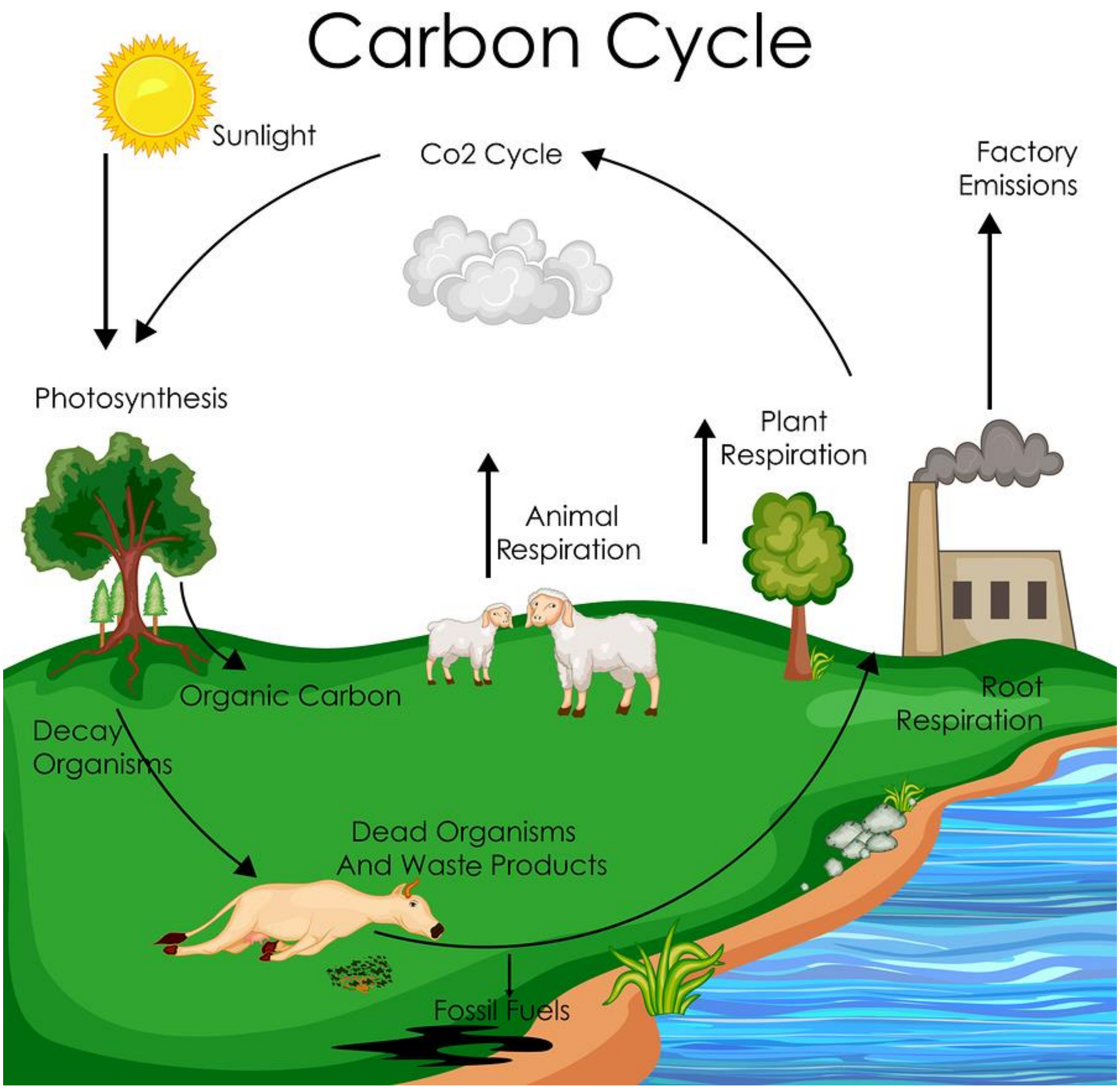
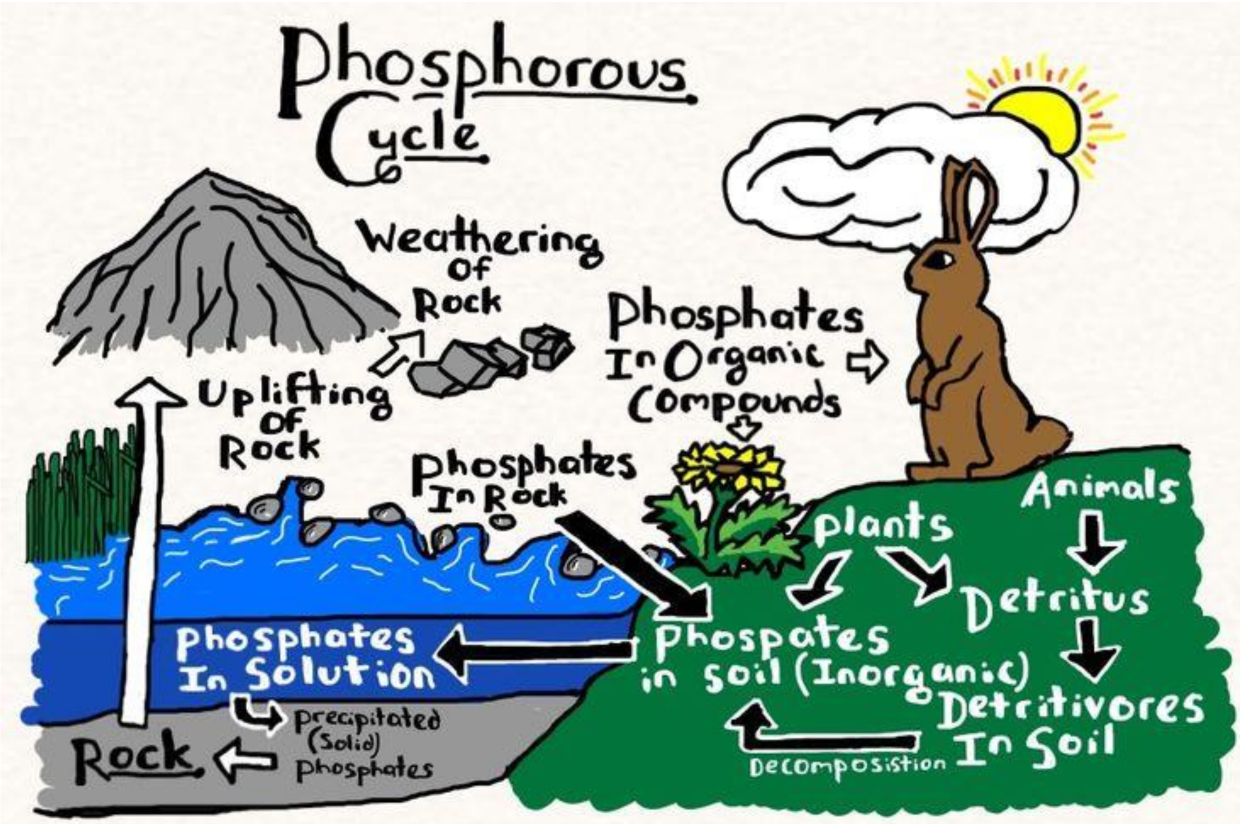


Figure 3.4.3: Phosphorus Cycle (suggested image)



https://www.pinterest.com/pin/327566572870997643

Fertilizer Experiment

Today we discussed the cycling of nutrients and carbon through natural systems and how these biogeochemical cycles support plant growth and the production of food. In this experiment we will test 2 different rates of 2 different fertilizer sources (4 treatments total) to see if/how they affect plant growth. The details of each treatment are included in Table 1.

Table 1.

		Fertilizer Rate	
		High Rate, H	Low Rate, L
Fertilizer Source	Elemental Fertilizer, E	1 teaspoon	¼ teaspoon
	Organic Fertilizer, O	1 teaspoon	¼ teaspoon

The materials needed by each design team for this experiment include:

- A measuring cup or graduated cylinder
- Measuring spoons, ¼ tsp. And 1 tsp.
- Digital pocket scale
- Weighing scale
- An empty mixing cup
- Elemental fertilizer
- Organic fertilizer
- Water
- Calculator
- Research Notebook and pencil

Steps:

1. Design teams should start out by labeling each of the seeded plastic cups with the appropriate treatment code (e.g. EH=Elemental fertilizer, high rate, OL=Organic fertilizer, low rate). This experimental design and coding system should also be recorded in each students' STEAM Research Notebook.

Fertilizer Experiment (continued)

2. Next, students should document in their notebooks the fertilizer nutrient analysis of each fertilizer source. This is represented as a 3 number code (XX-XX-XX) that represents the percent Nitrogen-Phosphorus-Potassium contained in the fertilizer.
3. Fertilizers should then be measured and weighed on the scale to determine the fertilizer mass represented by each of the volumes of fertilizer. Don't forget to weigh the measuring spoon before and after loading it with the fertilizer so that you may subtract the weight of the spoon to get the actual mass of fertilizer.
4. Next, calculate the exact amounts of Nitrogen and Phosphorus contained in the High and Low Rate treatments for each fertilizer source and record in your notebooks. This is calculated using the following equation:

$$Fertilizer\ Mass\ x\ Nutrient\ Percent = Nutrient\ Mass$$

5. Mix the measured amounts of fertilizer with 100-125 mL of water in an empty mixing cup until fully dissolved. This fertilizer water should be added to the appropriate plastic cup labeled with the treatment corresponding to that fertilizer source and rate combination.
6. Finally, weigh each cup and record the plant height of the bean plants. Results should be included in your STEAM Research Notebook.

3.5 SESSION FIVE - Ecosystem Services Everywhere - 40 minutes

In Session Five, students will learn about the benefits the natural world bring to our households, communities, and economies through ecosystem services. The ecosystem provides humans with many items and services that are essential for sustaining life and enhancing the quality in our lives. Students will learn about the four main kinds of ecosystem services: supporting, provisioning, regulating, and cultural services. While each service has a different name, each type of service is closely related and students will see how one part of the ecosystem can provide services in all these areas. Activities will engage students in identifying and describing services they see in their own school yard. Students will incorporate their learning into the design of their greenhouse prototypes.

3.5.1 Teacher Preparation, Session Five

The teacher should assemble materials, duplicate handouts, and preview videos used in the session. The teacher can find additional information on ecosystem services concepts from *Nature's Services: A guide for primary school on ecosystem services* - http://www.wwf.se/source.php/1539893/Ecosystem-services-3.pdf reference in the *Digital* Resources section. It is critical the teacher understand the concept of the four major ecosystem services: supporting, provisioning, regulating, and cultural services; and how they can be identified and applied in everyday life. The teacher should review the Ecosystem Service Tic-Tac-Toe Game. Ecosystem Service Landscape Image Playing Cards have been provided; however, to give students more local context, the teacher could prepare images from local landscape sources the students are familiar with. As with previous sessions, the teacher should ensure students tend bean seed growing chambers, and make observations on their bean plant experiments in their STEAM Research Notebook.

Digital Resources:

Nature's Services: A guide for primary school on ecosystem services - http://www.wwf.se/source.php/1539893/Ecosystem-services-3.pdf

Student Materials:

STEAM Research Notebook,

Pen or Pencils (multiple colors)

Other Materials (1 per design team):

Soil Thermometer

Weighing Scale

Ruler

Water

Scissors

Tablet or Digital Camera (optional)

Handouts:

Ecosystem Service Tic-Tac-Toe Game Board

Ecosystem Service Landscape Image Playing Cards

Table 3.5 Explicit Knowledge for Session 5

Core Area	**Knowledge Required**	**Supports for Student Learning**
Science	Students should understand that the food of almost any kind of animal can be traced back to plants. Organisms are related in food webs in which some animals eat plants for food and other animals eat the animals that eat plants. Some organisms, such as fungi and bacteria, break down dead organisms (both plants or plants parts and animals) and therefore operate as "decomposers." Decomposition eventually restores (recycles) some materials back to the soil. Organisms can survive only in environments in which their particular needs are met. A healthy ecosystem is one in which multiple species of different types are each able to meet their needs in a relatively stable web of life. Newly	The teacher will facilitate and ecosystem services based Tic-Tac-Toe game, which will build and develop student comprehension of ecosystem components and interactions, and then extend that to the idea of ecosystem services.

	introduced species can damage the balance of an ecosystem.	
Mathematics	Students should be able to take brief notes on experiments and sort evidence into provided categories.	Teachers will provide support during the sessions to make sure student teams are recording and gathering feedback from experiments and classmates.
	Students should be able to use measurement tools to make measurements and collect data; use rulers, scales, measuring cups, and thermometers to make observations about plants and growing conditions.	Teacher will provide examples of how to use measuring spoons and scales for students when necessary.
	Students should be able to calculate the mean, median, and mode of a given sample and use these statistical measurments to compare with other sample data.	Teacher can provide guidance by demonstrating examples in class and providing opportunities for students to practice.
	Display and interpret numerical data in plots and graphs	The teacher will provide support through discussion and interpretation of data.
Language Arts	Students should be able to write narrative text about their experiences using effective technique, descriptive details, and clear event sequences. Students should understand the value of reflection and the habit of summing up their learning.	A writing rubric is included in the STEAM Research Notebook for students to use to self-assess their writing. The teacher will provide models of explanatory writing and science notebooks using books illustrating science notebooks such as the one recommended in Session 1.
Art	Students should be able to analyze landscape images provided to match realworld concepts in nature. Students should be able to use digital device to take photograph.	The teacher will provide feedback on student team choice of artistic representations. The teacher will provide models and explanation of how to take a photograph of a landscape.

3.5.2 Introduction - 5 minutes

Begin Session Five by reminding students of the challenge for the unit. Lead a discussion with students tying together concepts from Sessions Three and Four drawing connections between earth's biogeochemical cycles and how those interact with living things to form ecosystems. Ask students to brainstorm ideas about what other natural system processes happen in the environment to help food grow, guiding students to understand that humans have learned from observing nature's interactions how to create and develop their own human ecosystems to grow and cultivate crops and livestock for a growing population. However, these agricultural ecosystems (i.e. agroecosystems) are challenging to manage, control, and sustain. Lead students to conclusion that the ecosystem provides humans with many items and services that are essential for sustaining life and enhancing the quality in our lives. The benefits that people get from healthy ecosystems are called *ecosystem services.* Tell students that these ecosystem services are classified as one of four types: supporting, provisioning, regulating, and cultural services and how each type of service is closely related(see 5.1 Appendix B Vocabulary and *Nature's Services: A guide for primary school on ecosystem services* - http://www.wwf.se/source.php/1539893/Ecosystem-services-3.pdf)

3.5.3 Activity - Ecosystem Services Tic-Tac-Toe and Scavenger Hunt - 25 minutes

Students will apply their knowledge about earth processes and ecosystems as they play Ecosystem Services Tic-Tac-Toe and go on a Scavenger Hunt in their schoolyard to identify and classify different types of ecosystem services.

1. Write the words *supporting, provisioning, regulating, and cultural services* on the board. Let students discuss their understanding of these words and guide them to relating them to the environment and ecosystem.
2. Pass out the 'Ecosystem Services Tic-Tac-Toe' handouts which include the game board and landscape image playing cards. Ask students to cut out the playing cards that will be used on the 'Tic-Tac-Toe' game board. Give instructions to students: The object of Tic Tac Toe is to fill in three squares in a row on a three by four game board. The first player is known as X and the second is O. Students will each get a set of landscapes to cut out, and place an X or O on the backside of the card. Players alternate placing Xs and Os on the game board until either opponent

has three in a row or all twelve squares are filled. To place their X or O on the game board students must justify whether the landscape on the piece is a *supporting, provisioning, regulating, and cultural service* in order to play. Each team will play with two players ('X' and 'O') and two judges whose job is to review and evaluate where X and O provided adequate justification for the ecosystem service square they filled with their landscape.

3. Once students are finished with the Tic Tac Toe Game, lead a discussion, asking: Where did you place the landscapes and why? Which of the landscapes were harder to place than others? Did any of the landscapes fit in more than one category?
    a. As an alternative option for incorporating more art, have students take landscape photos around the school and schoolyard. Have them work with a photo-editing program to tag the images with the differetn types of ecosystem service classifications.
4. Now, take students outside into the school yard for an ecosystem scavenger hunt. Have students find a tree and either draw a picture or take a photo of the tree with the ground, the sky above, and anything they see as they look at the tree (encourage students to capture as many details of the tree as possible). This is a great way to incorporate landscape and macro photography into the class activity.
5. Have students investigate how all these images are connected to ecosystem services. Looking at the picture they drew or photos they captured, have students share with a partner what they observed about the ground underneath the tree, asking students guiding questions such as: Were there grass, rocks, mulch? Could you see soil? What did the soil look like? Why is that soil important to the tree? What type of ecosystem service does that soil provide? How does soil *support* all ecosystem services? Ask students to look at the tree and ask: What kind of leaves, flowers, and other items does the tree have?
6. Have students write down all the benefits the tree provides to other organisms (e.g. pollination resources, habitat, shelter, oxygen, food, shade, leisure, etc.). Sometimes humans cut down trees to change how the land is used. How we *regulate* land, trees, and resources affects services we

get from them. Lead students through discussion connecting the words *Regulating, Provisioning, and Cultural Services* to the benefits the tree provides listed in the previous question.

3.5.4 Wrap-Up and STEAM Research Notebook Entry– 10 minutes

Design Teams should take measurements from the samples from the Light Chamber Experiment and Fertilizer Experiment and record results and observations in their STEAM Research Notebooks. Measurements should include the weight and soil temperature from each of the Light Chamber Experiment samples and the weight and plant height from each of the Fertilizer Experiment samples. Students can take note of any other visual observations as well. Recordings should include a notation of the total sample size (how many measurements have been collected) and a calculation of the mean and median. Design teams should report to the class measurements of each treatment sample and the teacher should graph results on a chart that is displayed in the classroom. Following these measurements, if the samples appear to be drying out, students should add a small amount of water (~25-75 mL) to the sample. This water should first be weighed and notated in their STEAM Research Notebook so that students can account for this in their sample weight calculations.

Ask the students to write and reflect in their STEAM Research Notebooks about the day's discussions and activities, answering the questions: What are *Ecosystem Services - Supporting, Regulating, Provisioning, and Cultural?* How do we alter our ecosystem so that it affects the abundance of these services? What can you do to sustain these ecosystem services? How will you incorporate ecosystem services into your greenhouse prototype design?

3.5.5 Deliverables for Session Five

At the end of the session, students should have completed the following:

- Completed Tic Tac Toe game and participated in class discussion about classifying landscapes according to the ecosystem service they provide.
- Photo Scavenger Hunt pictures
- Recorded weight and plant height measurements from the Fertilizer Experiment and weight and soil temperature from the Light Chamber Experiment. Results should be recorded in students' STEAM Research Notebooks.
- Entry in STEAM Research Notebook

3.5.6 SESSION FIVE RESOURCES

Ecosystem Services Tic Tac Toe Handouts:

- Ecosystem Service Tic-Tac-Toe Game Board
- Ecosystem Service Landscape Image Playing Cards

Figure 3.5.1: Ecosystem Service Landscape Image Playing Cards

ECOSYSTEM SERVICES TIC-TAC-TOE

Figure 3.5.2: Ecosystem Service Tic-Tac-Toe Game Board

ECOSYSTEM SERVICES TIC-TAC-TOE

SUPPORTING			
REGULATING			
PROVISIONING			
CULTURAL			

3.6 SESSION SIX - Crops and Soils - 40 minutes

This session will introduce the idea of soil being the growth medium for plants and the area where they access water, nutrients, and space for growth. Soils are variable in their ability to hold and supply water and nutrients to crops. Certain characteristics are fixed (e.g. soil texture) and others can be managed or regulated (e.g. organic matter can be added). Students will investigate soil samples and conduct experiments on the water holding capacity of different soils.

3.6.1 Teacher Preparation, Session Six

The teacher should assemble materials, duplicate handouts, and preview videos used in the session. Areas in the schoolyard students can collect soil samples should be identified and teacher should ensure permission ahead of time. The lesson uses sand, gravel, and the student collected soil sample in the water retention experiment to easily demonstrate the differents in water holding capacities of different soil properties; however, additional soil components such as clay, silt, and other soil mixes could be incorportated into the lesson. Review, setup, and test the experiment ahead of time to ensure smooth transitions and optimal student experience.

The teacher should ensure students tend bean seeds, and make observations on their bean plant experiments in their STEAM Research Notebook.

Teacher Materials:

Read Book: *Dirt: The Scoop on Soil* by Natalie M. Rosinsky (Optional)

Digital Resources:

Soil Basics for Teachers - http://www.soils4teachers.org/soil-basics

Soil Experiments for children: http://www.fao.org/3/a-i7957e.pdf

youTube video: *Who needs dirt?* - https://www.youtube.com/watch?v=eCSIrlk0GTs

Internet access (Optional)

Student Materials:

STEAM Research Notebook

Pen or Pencils (single or multiple colors)

One quart jars with tight covers and blank labels (1 per student)

Other Materials (1 per design team):

Newspaper or plastic to cover tables

Gravel (0.5 cup per group)

Sand (0.5 cup per group)

Soil collection kit for each student

- A plastic container for soil
- Measuring cup

Soil-water filter (see Soil Filter Image)

- Quart jar, or recycle a two-liter plastic bottle
- Plastic funnel
- Coffee filter

Hand spade or large spoon

Digital camera

Magnifying glasses, tweezers, utensils, and other small tools for teams to share

Graduated cylinder (to measure water)

Water

Paper plate

Microscopes (Optional)

Handouts:

Layers of Soil

Soil Filter Image

Table 3.6 Explicit Knowledge Required for Session Six

Core Area	Knowledge Required	Supports for Student Learning

Science	Students should understand that matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die.	Through a series of experiments supported by the teacher, students will identify controlling factors in plant growth and biogeochemical cycling and how these factors can be controlled.
Mathematics	Students should be able to write and interpret numerical expressions, and analyze patterns and relationships.	Students will use measurement tools to make measurements and collect data, and use numbers to report relationships between variables and report numerical quantities to answer simple questions on their experiments.
	Students should be able to calculate the mean, median, and mode of a given sample and use these statistical measurments to compare with other sample data.	Teacher can provide guidance by demonstrating examples in class and providing opportunities for students to practice.
	Display and interpret numerical data in plots and graphs	The teacher will provide support through discussion and interpretation of data.
Language Arts	Students should be able to write narrative text about their experiences using effective technique, descriptive details, and clear event sequences. Students should understand the value of reflection and the habit of summing up their learning.	A writing rubric is included in the STEAM Research Notebook for students to use to self-assess their writing. The teacher will provide models of explanatory writing and science notebooks using books illustrating science notebooks.

3.6.2 Introduction - 5 minutes

Begin Session Six with a quick review of the the four main kinds of ecosystem services: supporting, provisioning, regulating, and cultural services. Ask students if they recall a component (soil) in the ecosystem that supports ALL other ecosystem services. Ask students, What is soil? Soil means many things to many people. Scientists might see it as mineral or organic. Engineers think of soil as building material. Agriculturists think of soil as a place to grow crops. Others think of soil as dirt. Review how soil supports all other ecosystem services.

Looking at soil can tell a story of where it comes from and how it is used. The soil could be a base for the roads on highways or for growing the food people eat. Soil is everywhere. Some soils has never been changed by humans, but other soils have been significantly altered for specific purposes. Either way, altered or untouched, soil is a critical factor in ecosystem success. In this session, students will take a look at the soil they see every day, and begin to investigate different properties of soil including soil layers and water holding capacity

3.6.3 Activity - Soil Detectives and Water Retention Experiments - 25 minutes

Session Six enables students to link their understanding of soil as an essential element in ecosystem services to the real world through soil investigations. A short (4 minute) video about how plants use different organs (leaves, stems, and roots) to get the nutrients they need to survive introduces the activity. During the video students will have first exposure to the concept of hydroponics that will be further explored in Session Eight activity 'Hydroponics in a Bottle.' In this lesson, students will focus on soils as the foundation of all terrestrial ecosystems that make our world livable. Students will collect soil samples from different locations across the school yard to investigate different soil properties.

1. Show the video *Who needs Dirt?* Discuss plant organs and what soil provides those organs with students.
2. Soil Detectives – Have students visit the school yard in their teams. Each student should collect a 2 cup soil sample. Team members should collect samples from different locations across the school yard where different plants are growing or not growing. They should place soil samples in quart jars with lids and label the area from which the sample was collected. Encourage students to collect from interesting places (e.g. playground, grassy areas, pond, etc.). Students should label each sample with a number and document each sample by writing a brief description of each of their teams' samples in their STEAM Research Notebooks, including a short description of where the sample was retrieved, as well as the time and weather conditions. Encourage students to record the plants and animals they see in the area also. If digital cameras are available, have students take a before and after pictures of soil site.

3. Have students remove a one small teaspoon size soil sample from each collection site out of the collection jar and place it on a paper plate. Then each student should add one cup of water to his or her sample, and shake the sample vigorously for 1 minute. Students should set the jars aside to allow all particles to settle and stratify for at least 10 minutes.
4. As students wait for soil and water mixture to settle and stratify, have them use a magnifying lens or microscope to explore particle size and surface area of the teaspoon size samples. For example, look at sand particles. It is hard to grow things in sand. The particle size and surface area in sand make it tough for plants to absorb nutrients. That's why fertilizer is used in a sandy soil if you want to grow things.
5. Point out to students that oxygen is also needed in soil where plants grow. Clay soil has more surface area and holds more water, but leaves little room for oxygen. This makes it hard for plants to pull nutrients out of this type of soil.
6. Tell students that how water is absorbed is another important element of soil. If particles in the soil are too large, water will run through the soil too fast, sweeping the nutrients away.
7. Tell students that organic matter such as compost and decaying plants and animals affects a soil's color. The more organic material you find in the soil, the darker the color of the soil. Ask students how they think that soil color relates to soil fertility, or soil's ability to support plant life.
8. Now have students look at their quart jars. Ask them if they see layers, and have them examine the soil layers from the soil sample and water mixture (once it has settled, the soil should separate into distinct layers). One location can have many layers of soil. Layers of soil may give a clue or even blueprint for what might be a good use for that soil. Look at each layer for organic material, minerals, and moisture. How do layers affect the health of a soil? Extension: Have students look up different soil profiles for different growing regions. Have students draw the different soil layers from one of their soil samples.
9. Now have students explore different soil components they might incorporate into their greenhouse prototype design (sand, gravel, and the soil they collected). Students will conduct a

water retention experiment to see how much water passes through sand, gravel, and the soil they collect in 2 minutes.

a. Each group should craft a water filter (see Soil Filter Image) composed of a container basin to collect water and a funnel lined with a coffee filter to hold dry soil matter.
b. Students should add ½ c of soil material to the coffee filter nested inside the funnel.
c. Students will then add50 mL of water to the soil material and wait for 2 minutes to see how much water filters through the soil and water filter.
d. Students will pour water that has filtered through the soil and coffee filter into the water basin into a graduated cylinder to measure how much water passed through filter.Which component holds the most water? The least? How might these soil holding water properties impact their decisions in the selecting soils for their greenhouse design?

3.6.4 Wrap-Up and STEAM Research Notebook Entry– 10 minutes

Design Teams should take measurements from the samples from the Light Chamber Experiment and Fertilizer Experiment and record results and observations in their STEAM Research Notebooks. Measurements should include the weight and soil temperature from each of the Light Chamber Experiment samples and the weight and plant height from each of the Fertilizer Experiment samples. Students can take note of any other visual observations as well. Recordings should include a notation of the total sample size (how many measurements have been collected) and a calculation of the mean and median. Design teams should report to the class measurements of each treatment sample and the teacher should graph results on a chart that is displayed in the classroom. Following these measurements, if the samples appear to be drying out, students should add a small amount of water (~25-75 mL) to the sample. This water should first be weighed and notated in their STEAM Research Notebook so that students can account for this in their sample weight calculations.

Ask the students to write and reflect in their STEAM Research Notebooks throughout the day's discussions and activities. In particular, ask students to consider the following questions: How does soil impact what crops are grown? What are some of the important properties to include when considering your soil mixture for your greenhouse? What kinds of issues and should you consider when developing your soil profile? What things have you learned about yourself and soil?

3.6.5 Deliverables for Session Six

At the end of the session, students should have completed the following:

- Recorded weight and plant height measurements from the Fertilizer Experiment and weight and soil temperature from the Light Chamber Experiment. Results should be recorded in their STEAM Research Notebook.
- Entry in STEAM Research Notebook
- Soil Detective Activities

3.6.6 SESSION SIX RESOURCES

Layers of Soil

Soil Filter Image

Soil - Water Experiment Image

Figure 3.6.1: Layers of Soil

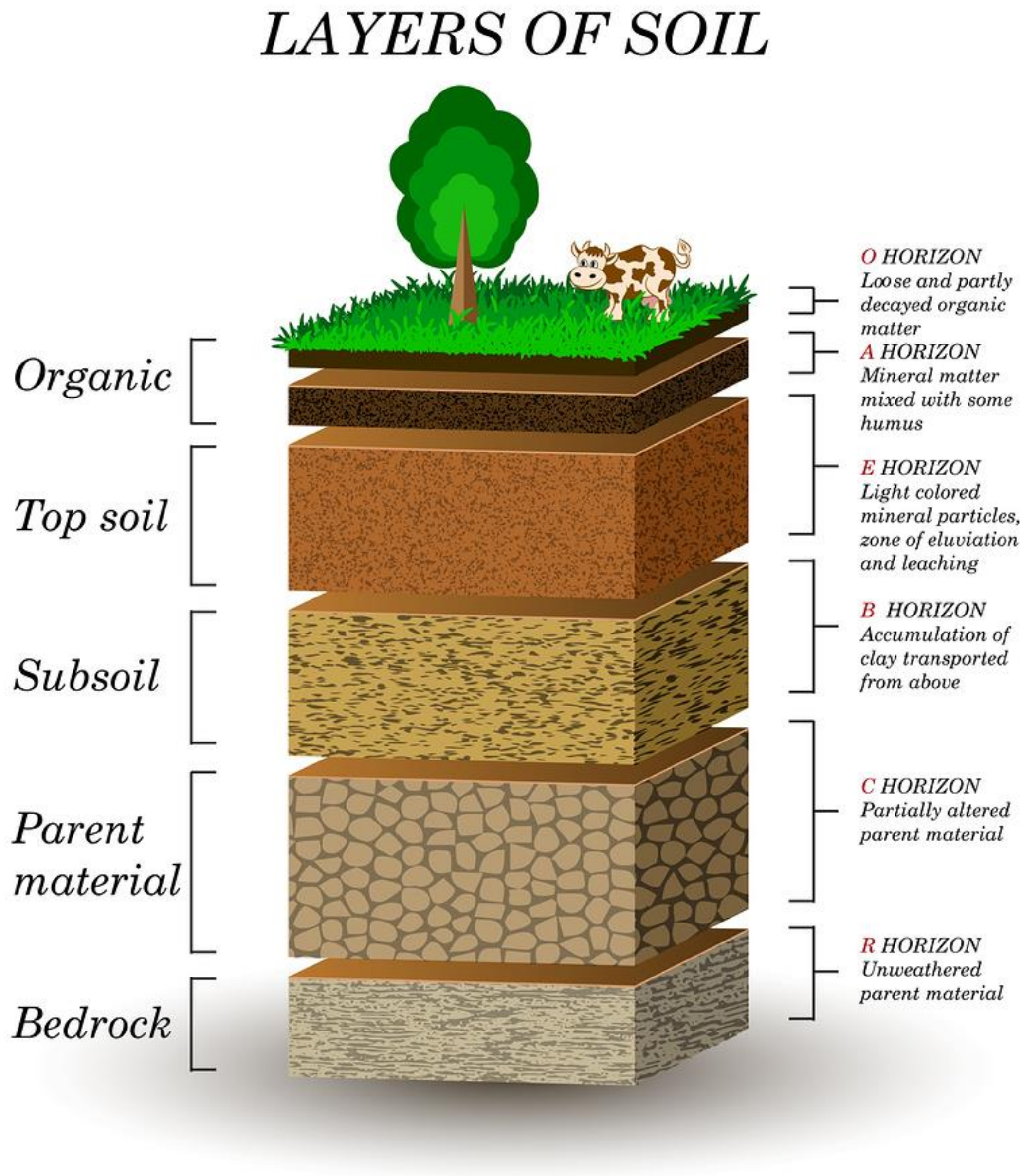


Figure 3.6.2: Soil Filter

3.7 SESSION SEVEN - Crops and Climates - 40 minutes

Session seven will engage students in exploring how crops and climate are related and how they together impact people. Different plants have different growing requirements. Some crops need warm temperatures during the growing season, while others grow better in cooler conditions. The amount of rain and sun and the air temperature vary from year to year and from location to location. Resilience to climate extremes can vary by crop and growth stage. In this session students will explore some the environmental factors that affect crop yields.

3.7.1 Teacher Preparation, Session Seven

The teacher should assemble materials, duplicate handouts, and preview videos used in the session. The teacher should prepare a presentation on a major climate related event that impacted human populations (e.g. Great Chinese Famine). The event should be something students can relate to locally. The point is to draw a clear link between climate, food, and people and how they strongly relate to eachother. Further, the teacher should draw a firm connection to why a the Unit Challenge – building a classroom greenhouse can control and modify the environment to help provide access to healthy food.

The teacher should ensure students tend bean seeds, and make observations on their bean plant experiments in their STEAM Research Notebook.

Teacher Materials:

Presentation on climate related event that impacted people (prepared by teacher)

Teacher-provided images and figures that represent different world climate zones emphasizing temperature and precipitation differences

Digital Resources:

FAO's Climate Change Page: http://www.fao.org/climate-change/en/

Internet access

Student Materials:

STEAM Research Notebook

Pen or Pencils (single or multiple colors)

Colored Pencils

Other Materials (1 per design team):

Soil Thermometer

Weighing Scale

Ruler

Water

Handouts:

Farm to Table

World Climate

Mexico Climate Zones and Charts Examples

China Outline Image

Table 3.7 Explicit Knowledge Required for Session Seven

Core Area	Knowledge Required	Supports for Student Learning
Science	Students should understand that climate describes a range of an area's typical weather conditions and the extent to which those conditions vary over years.	The teacher will represent data and graphical displays to describe type weather conditions expected during a particular season, and relate information to describe climates in different regions of the world.
	Students should recognize that natural hazards result from natural processes, but that humans can take measure to mitigate the impact of natural hazards.	The teacher will facilitate an engaging argument related to human responses and solutions to reduce the impact of natural hazards.
Mathematics	Students should be able to convert like measurement units within a given measurement system, and represent and interpret data.	Teacher will provide opportunities for students to learn from peers and demonstrate the interpretation of charts and graphs.
	Students should be able to write and interpret numerical expressions.	The teacher will provide support to student teams as they take measurements in the Light Chamber & Fertilizer Experiment.

	Students should be able to calculate the mean, median, and mode of a given sample and use these statistical measurments to compare with other sample data.	Teacher can provide guidance by demonstrating examples in class and providing opportunities for students to practice.
	Display and interpret numerical data in plots and graphs	The teacher will provide support through discussion and interpretation of data.
Language Arts	Students should be able to use communication skills including letters, words, and sentences to communicate their ideas.	Teachers will support students to articulate their ideas.
Art	Students should be able to represent realworld data in an artistic expression that clearly demonstrates information.	The teacher will provide examples for the students as well as feedback on their infographics.

3.7.2 Introduction - 10 minutes

Tell students that climate change and extreme weather events can affect food safety and nutrition. For example, extreme weather events such as flooding create challenges for food supply and distribution if fields, roads, and waterways are damaged or made inaccessible. Higher than normal concentrations of carbon dioxide in the air can act as a fertilizer for some plants, but also can lower the levels of protein and essential minerals in crops such as wheat, rice, and potatoes, making these food less nutritious. The food system involves a network of interactions with our physical and biological environments as food moves from being grown and cultivated in the fields to production and consumptions of that food (see Farm to Table handout). Ask students to respond to the following questions in a class discussion: How will climate change impact our food supply to feed a growing population? What can we learn from historical climatic extreme events from across the world (or keep it local to your community) that have impacted human health and disease?

Share an example such as the Great Chinese Famine (1959 - 1961) and discuss the contributions of drought and poor weather to the devastating impact on the human population of this event. What were the ramifications on the health of people, crop supply, and crop prices? Ask students how this impacted their families and how it makes them feel?

3.7.3 Activity - Climate and Crop Growth Analysis Activity - 20 min

In this activity, students will explore some of the environmental factors that affect crop yield. Discuss with students the differences between climate and weather. Provide images and figures that represent different world climate zones emphasizing temperature and precipitation differences. Working with partners, students will begin to interpret climate charts that show the temperature and profiles for different climate types and how different climates support different types of crops across the world and in China. Students will use Internet-based climate simulators to model and explore how different crops grow in different climate zones and how extreme weather events affect plant growth. Students will then explore their local climate and what crops grow within a 100 km radius of their school.

1. Begin with a discussion with students about the differences between climate and weather, asking questions such as: What environmental factors make up climate?
2. Present students with images of different world climate zones (e.g. World Climate handout). Ask students where they think the best place is to grow crops. Note that there are many places to grow crops; however, the type of crops grown varies and depends on the environmental conditions. Some places are better at growing citrus and other places are better at growing rice.
3. Introduce students to specific climate regions paired with climate graphs that describe temperature and precipitation averages over time (e.g. Mexico Climate Zones and Charts Examples). Work with students to interpret the example, and then have students partner to interpret their own climate data models.
4. Using an Internet-based climate and crop simulator, have students explore the Role of Climate in Crop Production. With their partners, have students go to High-Adventure Science's website: http://authoring.concord.org/activities/295/pages/1877/823ff30d-cb44-4a03-a273-ee0ffb1d2acd. On the website students, can adjust landscape and climate factors to visualize how well different crops grow in different climate zones. Guide students through questions such as: Given the

climate profile of a tropical rainforest in a plain, how well does wheat grow compared to grass during the month of May? Is more rain better for wheat or for grass in May?

5. Now have students work in pairs to research and investigate their local climate conditions and crops grown within 100 km of their school. Have students color and draw the climatic zones of China making sure students create a legend and key for their graphic (China Outline Image).
6. Students should then draw and design another China infographic that overlays some of the major crops produced through China's different climatic zones. Have students share and present their work with classmates (see Figure 3.7.2 for example).

3.7.4 Wrap-Up and STEAM Research Notebook Entry– 10 minutes

Design Teams should take measurements from the samples from the Light Chamber Experiment and Fertilizer Experiment and record results and observations in their STEAM Research Notebooks. Measurements should include the weight and soil temperature from each of the Light Chamber Experiment samples and the weight and plant height from each of the Fertilizer Experiment samples. Students can take note of any other visual observations as well. Recordings should include a notation of the total sample size (how many measurements have been collected) and a calculation of the mean and median. Design teams should report to the class measurements of each treatment sample and the teacher should graph results on a chart that is displayed in the classroom. Following these measurements, if the samples appear to be drying out, students should add a small amount of water (~25-75 mL) to the sample. This water should first be weighed and notated in their STEAM Research Notebook so that students can account for this in their sample weight calculations.

Ask the students to write and reflect in their STEAM Research Notebooks throughout the day's discussions and activities and consider questions such as: How does climate impact what crops are grown? What are some of the important climate properties to consider when designing your greenhouse? What things have you learned about yourself and climate?

3.7.5 Deliverables for Session Seven

At the end of the session, student teams should have completed the following:

- Recorded weight and plant height measurements from the Fertilizer Experiment and weight and soil temperature from the Light Chamber Experiment. Results should be recorded in their STEAM Research Notebook.
- Entry in STEAM Research Notebook
- Results from Climate and Crop Growth Analysis Activity
- Completed map of climatic zones in China

3.7.6 Resources

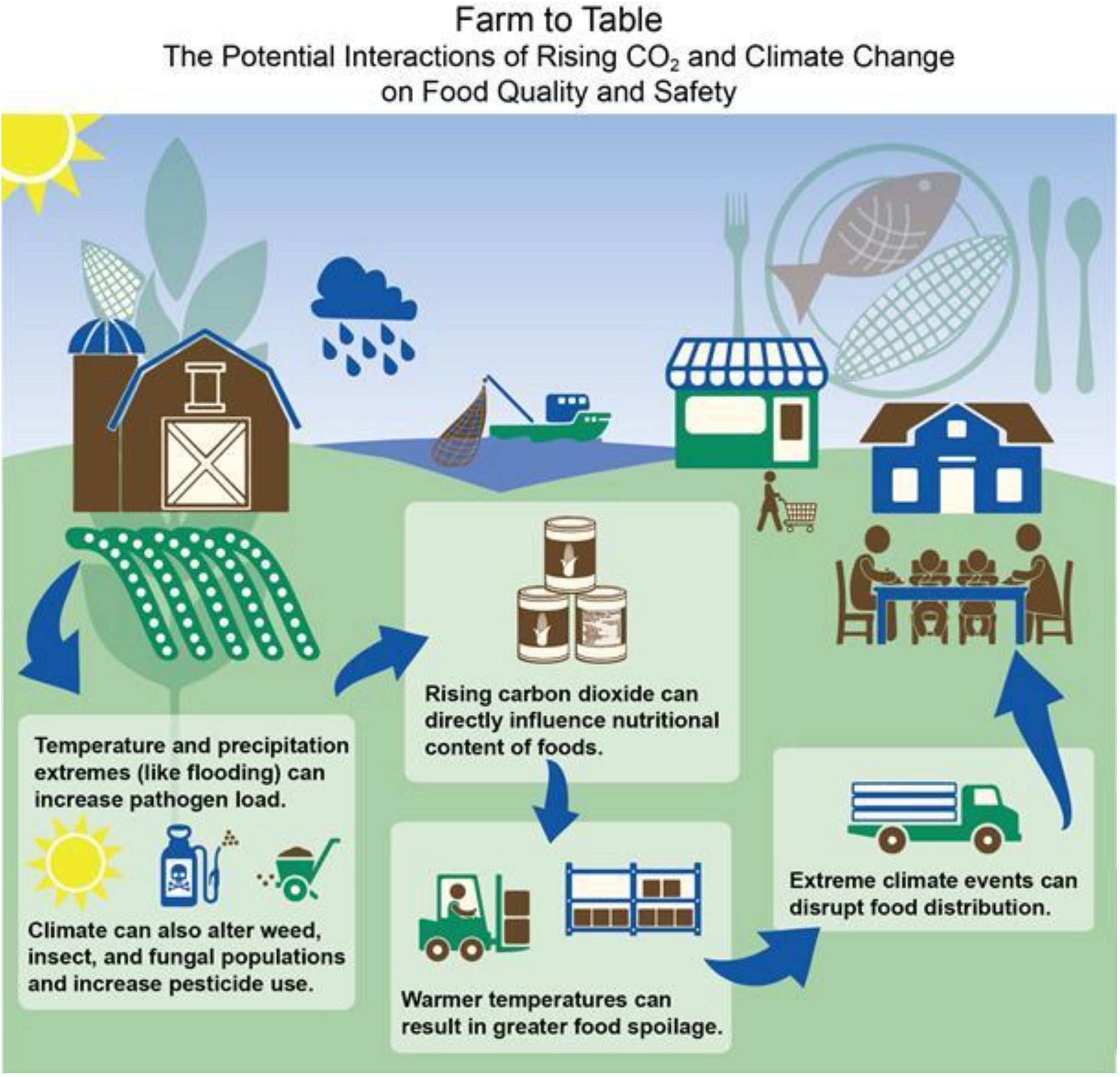
Farm to Table

World Climate

Mexico Climate Zones and Charts Examples

China Outline Image

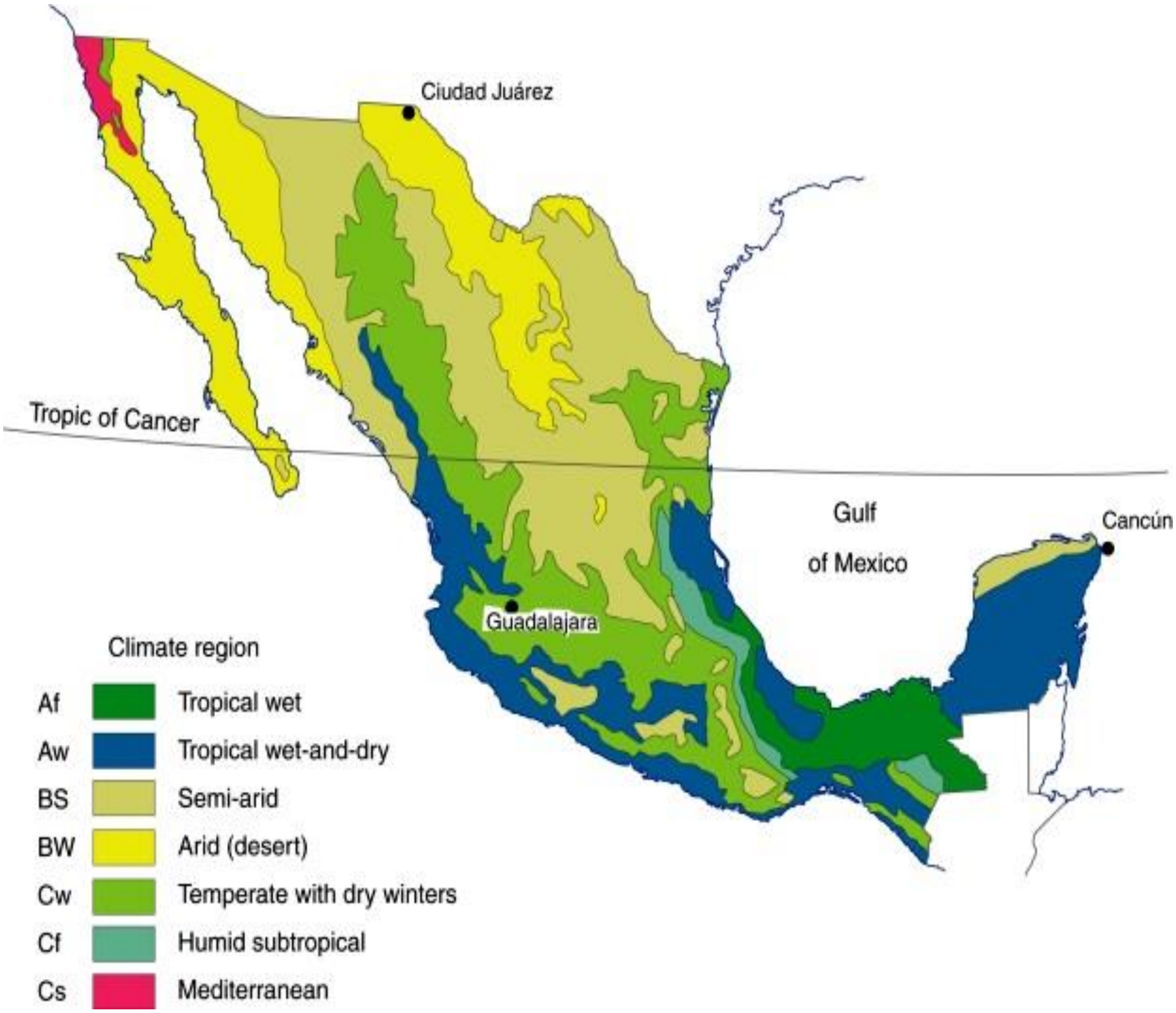
Figure 3.7.1 Farm to Table (suggested image)



The food system involves a network of interactions with our physical and biological environments as food moves from production to consumption, or from "farm to table." Rising CO2 and climate change will affect the quality and distribution of food, with subsequent effects on food safety and nutrition. Source: USGCRP (2016)

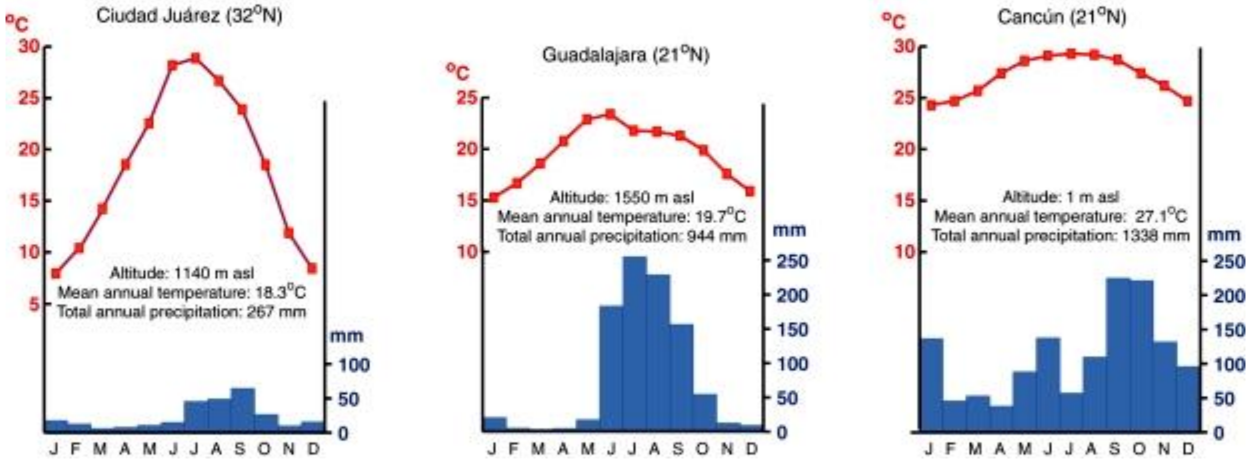
Figure 3.7.2: World Climate

Figure 3.7.3: Mexico Climate Zones and Charts Examples (*use a similar image for China data)



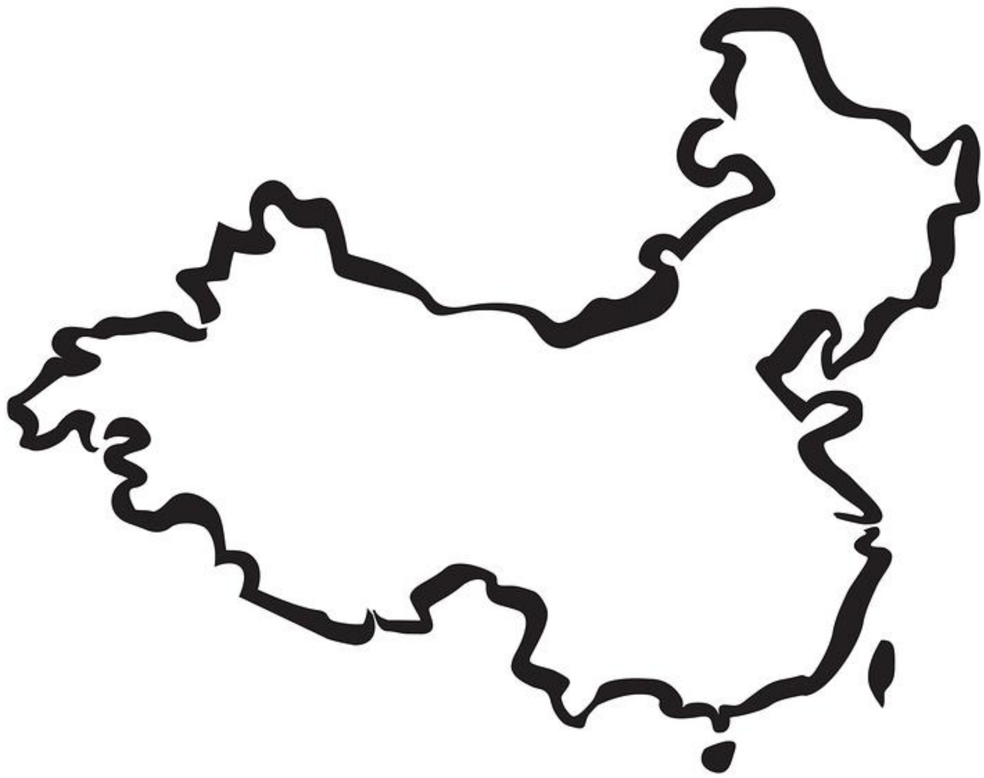
Major climate regions in Mexico. (Fig 4-5 of Geo-Mexico, the geography and dynamics of modern Mexico) [*http://geo-mexico.com/?p=9512*](http://geo-mexico.com/?p=9512)

Mexico Climate Zones and Charts Examples (continued) (*use a similar image for China data)



Climate graphs for three cities. (Fig 4.6 of Geo-Mexico, the geography and dynamics of modern Mexico)http://geo-mexico.com/?p=9512

Figure 3.7.4: China Outline Image



3.8 SESSION EIGHT - Controlled-Environment Agriculture - 40 minutes

Students will learn about different types of controlled-environment agriculture (CEA) systems, such as greenhouses and hydroponics. Activities will compare and contrast how certain systems manage and control aspects of soil and climate that were presented in earlier sessions. Students will work together in their design teams to construct their own hydroponics system.

3.8.1 Teacher Preparation, Session Eight

Teachers should assemble materials, duplicate handouts, and preview videos used in the session.

The teacher should experiment and build a sample hydroponics system in preparation to effectively lead students through this activity. The teacher The teacher should ensure students tend bean seeds, and make observations on their bean plant experiments in their STEAM Research Notebook.

Digital Resources:

Internet access

Student Materials:

STEAM Research Notebook

Pen or Pencils (single or multiple colors)

Other Materials (1 per design team):

2-liter bottle

Coconut coir fiber

Wicks

Aluminum foil

Hydroponic pH Control Kit (https://www.amazon.com/General-Hydroponics-pH-Control-Kit/dp/B000BNKWZY)

Measuring cup and spoons

Nutrients for hydroponic systems

5 Lettuce seeds (or other leafy vegetable)

Marker

Scissors

Soil Thermometer

Weighing Scale

Ruler

Water

Handouts:

Controlled-Environment Agriculture Systems

Hydroponics in a Bottle

Table 3.8 Explicit Knowledge Required for Session Eight

Core Area	Knowledge Required	Supports for Student Learning
Science	Students should understand that plants acquire their material for growth chiefly from air and water, and that matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment.	The teacher will provide background knowledge and examples about controlling factors in plant growth, biogeochemical cycling, and CEA systems
	Nature of scientific inquiry. Students should understand that scientists ask questions and use observations and measurements through thoughtfully designed inquiries to collect data about their questions. Scientists keep records of the data they collect and their ideas in scientific notebooks.	Teachers will review the purpose of the notebook and its format with students and will provide examples of scientists and their work.
	Students should be able to generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.	Teacher will provide feedback and guidance on the greenhouse designs.
Mathematics	Students should be able to analyze patterns and relationships between various CEA systems, noting pros and cons.	The teacher will provide background information and guidance with high quality support materials, including example products, teacher instruction, and online videos and/or tutorials.
	Students should be able to take brief notes on experiments and sort evidence into provided categories. Students will gather data from their Light and Fertilizer experiments and will discuss data with their groups and determine how changes can be accounted for.	Teachers will provide support during the sessions to make sure student teams are recording and gathering feedback from experiments and classmates.

	Students should be able to write and interpret numerical expressions.	The teacher will provide support to student teams as they make measurements and calculations.
	Students should be able to calculate the mean, median, and mode of a given sample and use these statistical measurments to compare with other sample data.	Teacher can provide guidance by demonstrating examples in class and providing opportunities for students to practice.
	Display and interpret numerical data in plots and graphs	The teacher will provide support through discussion and interpretation of data.
Language Arts	Students should be able to write narrative text about their experiences using effective technique, descriptive details, and clear event sequences.	A writing rubric is included in the STEAM Research Notebook for students to use to self-assess their writing.

3.8.2 Introduction - 10 minutes

The teacher should start the session with a discussion among students of what variables are involved in plant growth. Students should recall that in the previous sessions where they learned about a suite of variables that affect plant growth (e.g. water, light, nutrients and carbon, climate, soils, etc.). The teacher should point out that these are all variables that can be controlled with CEA systems, such as greenhouses.

- The teacher should distribute the Controlled-Environment Agriculture Systems handout. This handout lists the variables that can be controlled as well as different types of growing systems. Have the students get into their design teams. Design teams should spend 5 minutes discussing the following questions and think about how each of these systems impact and control the growing conditions for plants.
- Which systems are the most complex?
- Which systems are the most simple?
- Is there one system that you think controls water better than others?
- How is a hydroponic system able to grow plants without soil?
- Which ones would fit best as a design for our classroom project?

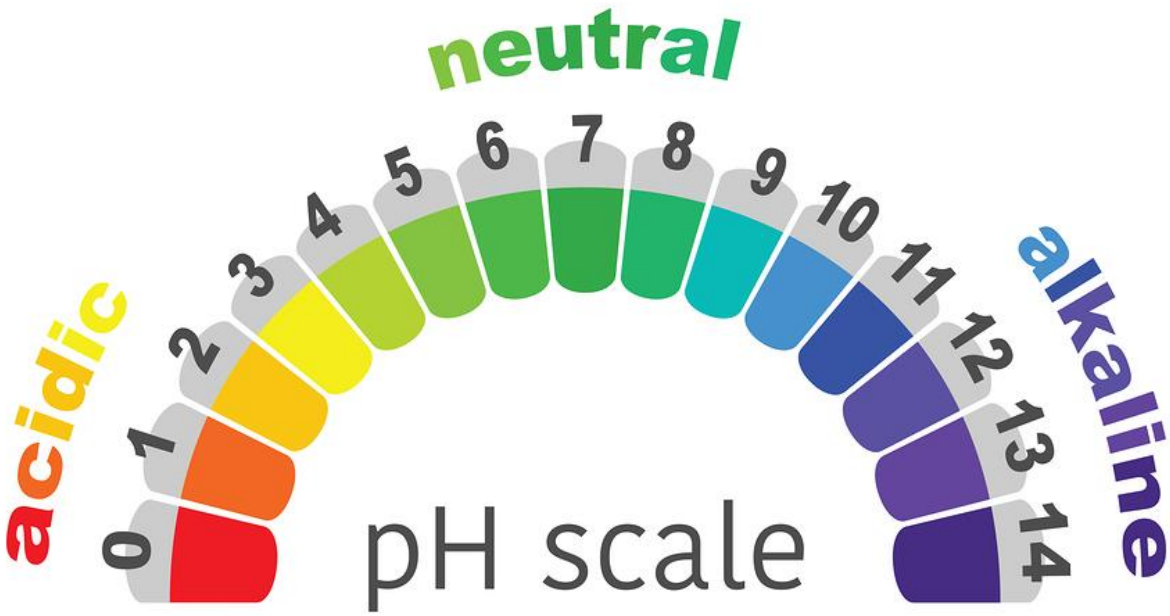
- Why do you think so?
- What are some pros and cons for each type of system?

At the end of this discussion period the teacher should facilitate discussion among the entire class about what they came up with for each of these questions and review the pros and cons they wrote down for each type of CEA system.

3.8.3 Activity - Hydroponics in a Bottle - 20 minutes

Following the discussion, and with students already in their design teams, the teacher should distribute the Hydroponics in a Bottle handout. The teacher should explain that in this activity students will be constructing their own simple hydroponics systems. The class should discuss what the primary components of a hydroponic system are and how they will be constructed during the activity. The teacher should explain the importance of water pH within hydroponic systems. pH is a measure of how acidic (positively charged) or alkaline (negatively charged) a solution or substance is and varies between 0 and 14. Pure water has pH of 7 so is considered neutral since it falls in the middle of the pH scale.

Figure 3.8.1: pH scale



Explain to students that pH is an important factor in how plants grow because it affects how certain substances, like nutrients, are absorbed and taken up by plants. If the pH drifts too far out of the ideal range for a plant, then it becomes much harder for that plant to absorb or take up the nutrients it needs to grow, even if there are plenty of nutrients in close proximity. When we grow plants in soil, the soil is where nutrients are held and made available to plants. Because soils are made up of materials such as clay and carbon, which also carry weak electrical charges, they have the ability to buffer, or hold steady, pH levels even as more acids or bases are added to it. Water on the other hand, which is relied on to hold nutrients in solution and deliver them to the plant in soil-less systems like hydroponics, lacks this buffering capability so the maintenance and management of pH is critical to making sure plants have access to the full range of nutrients being supplied in solution. Most hydroponic systems will gradually increase in pH over time, requiring some type of pH correction to be added to the water. The teacher should instruct the students that as part of this activity they should test and adjust the pH of their water before adding nutrients to make the solution.

At the end of this activity the teacher should ask students to brainstorm a solution that would allow for easy refilling of the hydroponic bottle's reservoir.

3.8.4 Wrap-Up and STEAM Research Notebook Entry- 10 minutes

Following the Hydroponics in a Bottle activity, design teams should take measurements from the samples from the Light Chamber Experiment and Fertilizer Experiment and record results and observations in their STEAM Research Notebooks. Measurements should include the weight and soil temperature from each of the Light Chamber Experiment samples and the weight and plant height from each of the Fertilizer Experiment samples. Students can take note of any other visual observations as well. Recordings should include a notation of the total sample size (how many measurements have been collected) and a calculation of the mean and median. Design teams should report to the class measurements of each treatment sample and the teacher should graph results on a chart that is displayed in the classroom. Following these measurements if the samples appear to be drying out, students should add a small amount of water (~25-75 mL) to the sample. This water should first be weighed and notated in their STEAM Research Notebook so that students can account for this in their sample weight calculations.

Each student should spend the final 5 minutes of the session completing a STEAM Research Notebook entry on what they learned regarding what factors are managed in CEA systems. Students should focus on writing down key points from the discussion, any remaining questions they have following the discussion, and ideas about how they might address certain constraints or factors in their greenhouse prototype design.

3.8.5 Deliverables for Session Eight

At the end of this session students should have completed the following:

- Worked in design teams to construct a model of a hydroponic growing system
- Recorded weight and plant height measurements from the Fertilizer Experiment and weight and soil temperature from the Light Chamber Experiment. Results should be recorded in their STEAM Research Notebook.
- Completed ta STEAM Research Notebook entry

3.8.6 SESSION EIGHT RESOURCES

Controlled-Environment Agriculture Systems

Hydroponics in a Bottle

Controlled-Environment Agriculture Systems

Controlled-environment agriculture (CEA) systems are production systems that are capable of controlling and managing a range of environmental conditions and variables that affect plant growth and production. These often include:

- Water (quantity, quality)
- Light (duration, intensity, spectrum)
- Temperature and Humidity
- Nutrients

These systems may be simple in design or very high tech but the goal is often similar. The goal of many CEA systems is to achieve extremely high levels of production while doing so in the most efficient way possible. Below a few types of CEA systems are described. Take a minute to review how these systems control the environmental variables described above. Write down a few pros and cons for each system.

Controlled-Environment Agriculture Systems (continued)

<table>
<tr><td>Type of System</td><td>Primary Variables Controlled</td></tr>
<tr><td>
Figure 3.8.2: Field/Plot Cover - http://www.conservationwebinars.net/webinars/high-tunnel-systems

Field/Plot Covers: These are the least expensive systems, can often be moved around or modified as needed or taken down temporarily, and require little to no power. However, in areas with harsh weather these structures can be damaged more easily than others or may only be able to marginally extend the growing season. These systems provide the least amount of control over growing conditions and rely on the natural soils on-site to support crops. A wide variety of crops can be grown with these systems and irrigation can be added to provide greater control of water availability.</td><td>Light
Temperature/Humidity</td></tr>
<tr><td colspan="2">Pros:

Cons:</td></tr>
</table>

Controlled-Environment Agriculture Systems (continued)

Figure 3.8.3: Greenhouse -
http://www.greenhousemegastore.com

Greenhouses: These systems are permanent or semi-permanent structures that provide a higher level of control over growing conditions and can greatly extend growing seasons outside of what is typically capable for that area. On-site soils may be used or custom soil mixes may be provided if crops are container-grown. greenhouses require greater amounts of power, particularly if supporting artificial lighting and indoor climate control. If climate control is not provided, some type of venting must be provided during periods of high temperature. A wide variety of plants can be grown and irrigation can be added to provide greater control of water availability.

Light
Temperature/Humidity

Pros:

Cons:

Controlled-Environment Agriculture Systems (continued)

Figure 3.8.4: Hydroponic garden – http://www.essexvalleyschool.org/news-and-events-1/2017/9/24/the-future-of-agriculture-hydroponic-garden-class

Hydroponics: This system relies on a system of growing plants without any soil at all! Here, crops and their roots grow within a soilless medium (like small gravel or fibers) and a nutrient-water solution is continuously cycled through the medium where it is taken up. This system occurs within greenhouses or similar buildings and often requires additional power to supply pumps for moving or aerating water. Since there is nearly total control over water and nutrient supply, and little energy is needed to be expended by the crop to access these resources, crops are able to grow quickly and produce high yields with the least amount of inputs. A variety of crops can be grown but production often becomes more difficult and expensive for deeper rooting crops.

Water
Light
Temperature/Humidity
Nutrients

Pros:

Cons:

Hydroponics in a Bottle

In this exercise, design teams will create their own hydroponics system using common materials from around the house. Hydroponic systems are a type of controlled-environment agriculture (CEA) system that allow for a high level of management over water and nutrient supplies for the plant. The most basic components of a hydroponic systems include:

- Reservoir: This is where the water-nutrient solution is stored that will be used to feed the plant
- Growing medium: This provides physical structure and growing space for the roots.
- Water transport mechanism: To ensure plants are able to access the water-nutrient solution
  OR
- Water aeration mechanism: Plant roots can grow directly in water, but that water needs to be well aerated with oxygen in order for this to work

Today, you will be constructing a system referred to as a wick hydroponic system. Here the wick is the water transport mechanism that moves the water-nutrient solution from the reservoir to the growing medium where plant roots can access it.

Material List

- 2-liter bottle
- Coconut coir fiber
- Wicks
- Aluminum foil
- pH kit
- Measuring cup and spoons
- Nutrients for hydroponic systems
- Lettuce seeds (or other leafy vegetable)
- Marker
- Scissors
- Pencil
- STEAM Research Notebook

Steps

1. First you will prepare the bottle. Using your marker, draw a line below the curved neck of the bottle where it transitions into the consistent diameter of the body. Cut the bottle along this line using a scissors. Now invert the neck of the bottle, so that the spout is pointing down, and place it on top of the body. The inverted neck of the bottle represents the growing area and the body of the bottle the reservoir for your water-nutrient solution. This is the basic structure of your hydroponic system (Figure 3.8.5 Hydroponic System Structure).

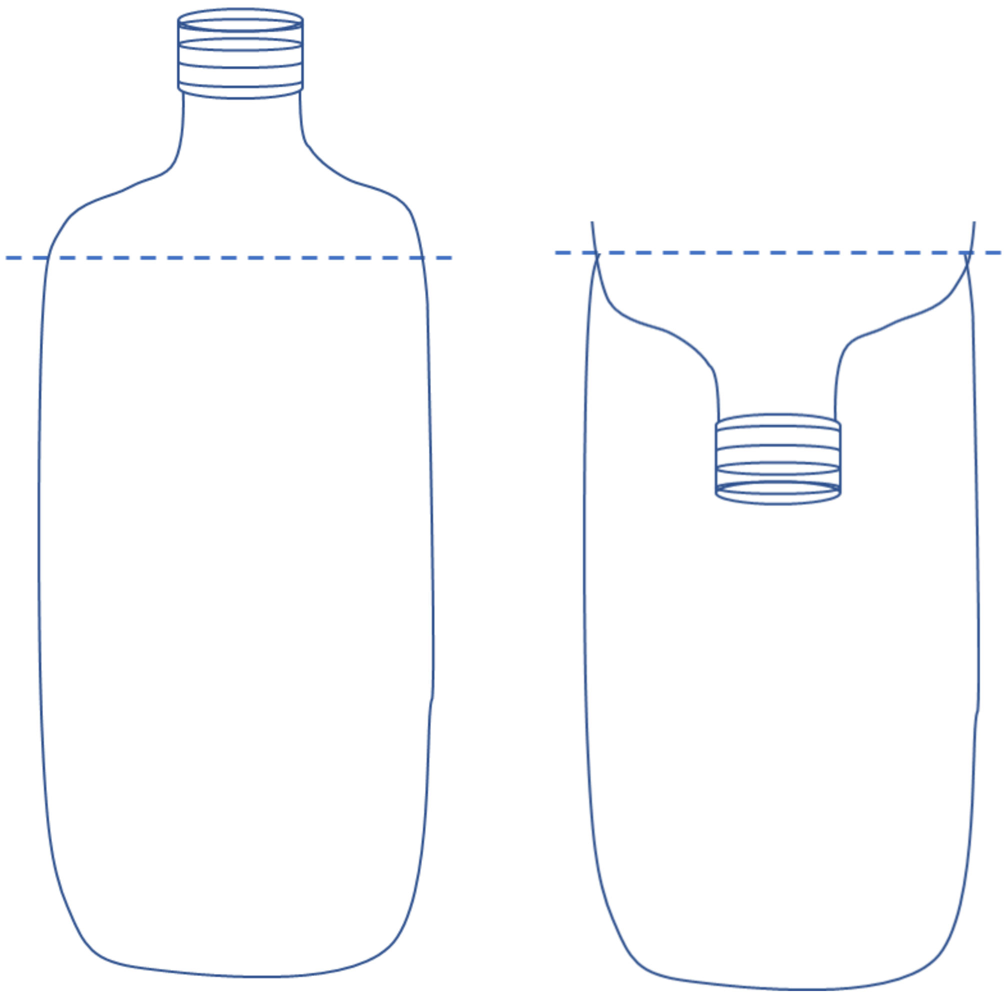


Figure 1. Basic structure of 2-liter bottle hydroponic system

2. Next, we need to test the pH of our water and adjust BEFORE adding the nutrients to make our water-nutrient solution. Follow the directions on your pH test kit to test the pH of the water. Ideally you want to have the water at a pH of around 6. If the water does not achieve this level,

add a few drops at a time of either pH UP or pH DOWN to your container of water, mix around, and retest. Repeat this as necessary until you get a pH of test of 6.

3. Once the pH of the water has been corrected we can add in the nutrients based on the instructions given on the label. We will need roughly 1 liter of water-nutrient solution. Using the proportions specified on the label, adjust the amount of nutrients accordingly to make 1 liter of water-nutrient solution. Pour this into the bottom of your 2-liter bottle. The water-nutrient solution should be at a level of at least the spout of the bottle.
4. Next insert the wick through the bottle spout. The wick should extend from just below where the surface of the growing medium will be to the bottom of the reservoir containing the water-nutrient solution.

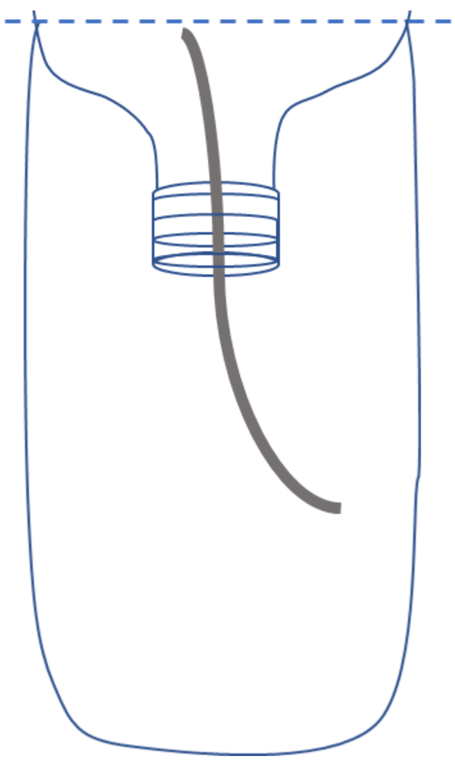


Figure 3.8.6. Wick inserted into 2-liter hydroponic system

5. Wet some of the coconut coir fiber and add it to the growing area of the 2-liter bottle. Continue adding wetted coconut fiber making sure the wick extends up through the growing medium. Once your growing area is full, make a small depression with your finger in the coconut coir

fiber. Add 4-5 lettuce seeds and lightly cover with wetted coconut fiber and tamp lightly with your finger.

6. As a final step, wrap the entire body of the bottle with aluminum foil to block out light to the water-nutrient reservoir. This blocks light and limits the growth of any algae or other organisms in your water-nutrient solution.

Hydroponics in a Bottle, continued

Watering Challenge

As plants grow in your hydroponic bottle and take up water from the wetted coconut coir fiber, the wick will transport additional water from the water-nutrient reservoir below to keep the growing medium saturated. However, over time the reservoir will need to be refilled. You and your team should brainstorm a system that would allow you to monitor the water level in the reservoir and easily add additional water-nutrient solution to the reservoir without having to lift off the top of the growing container. You can spend a few minutes online researching about siphons and self watering pots.

3.9 SESSION NINE - Designing and Managing Controlled-Environment Agriculture Systems - 40 minutes

Students will learn about requirements and considerations in designing and managing controlled-environment agriculture (CEA) systems such as greenhouses. During the activity, design teams will work together to develop growing plans to achieve various goals given different scenario constraints.

3.9.1 Teacher Preparation, Session Nine

Teachers should assemble materials and duplicate handouts used in the session. A review on calculating the basic statistical measures of spread (i.e. range, variance, standard deviation) can be accessed at Khan Academy, given in the link under Digital Resources.

The teacher should ensure students tend bean seeds, and make observations on their bean plant experiments in their STEAM Research Notebook.

Digital Resources:

Measures of spread: range, variance & standard deviation (Khan Academy) – https://www.khanacademy.org/math/probability/data-distributions-a1/summarizing-spread-distributions/v/range-variance-and-standard-deviation-as-measures-of-dispersion

Internet access

Student Materials:

STEAM Research Notebook

Pen or Pencils (single or multiple colors)

Calculator

Scratch paper for calculations

Other Materials (1 per design team):

Soil Thermometer

Weighing Scale

Ruler

Water

Handouts:

Factors and Considerations in Greenhouse Design and Management

Greenhouse Production Challenge

Table 3.9 Explicit Knowledge Required for Session Nine

Core Area	Knowledge Required	Supports for Student Learning
Science	Students should understand that there are many kinds of plants on Earth and each is identified by its characteristics; there are differences between individuals of the same type of plant. Students will use their knowledge of plants and market values to develop a greenhouse growing plan.	The teacher will continue to support student growth of understanding of plants in this session.
	Students should be able to generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.	Students will draw comparisons between different types of growing systems that were designed to provide particular solutions with a limited set of available materials.
	Students should understand that the key to engineering is the design. Engineering uses science and technology to solve practical problems by designing solutions and manufacturing products and processes.	Teacher reviews the engineering design process (EDP) with students, providing an opportunity to discuss the various stages of engineering design.
Mathematics	Students should understand that a consumer is a person whose wants are satisfied by using goods and services. A producer makes goods and/or provides services. Students will use their understanding of consumers and producers to determine the best output of product given a set of modifiable variables.	The teacher will discuss with student teams strategies for meeting consumer needs given different variable constraints to consider.
	Students should be able to estimate summary statistics and	The teacher will provide examples of measurement,

	mathematical descriptors of datasets.	calculation, graphing/charting, and evaluation procedures as needed
	Students should be able to use the calculator for more complex operations, to solve the simple practical problems, to explore a simple mathematical law	The teacher will provide support to student teams as they make measurements and calculations.
	Students should be able to write and interpret numerical expressions.	
	Students should be able to calculate the mean, medianstatistical measures of spread of a given sample and use these statistical measurments to compare with other sample data.	Teacher can provide guidance by demonstrating examples in class and providing opportunities for students to practice.
	Display and interpret numerical data in plots and graphs	The teacher will provide support through discussion and interpretation of data.
Language Arts	Students should be able to use communication skills including letters, words, and sentences to communicate their ideas.	Teachers will support students to articulate their ideas.

3.9.2 Introduction - 10 minutes

The teacher should begin by explaining that there are a variety of factors and considerations that influence what type of CEA system is most appropriate and even what plants may be grown within a particular CEA system. Engineers must always think about what factors or considerations are limiting in their design. These represent constraints that must be met when developing the designs and management plans. The teacher should distribute the Factors and Considerations in Greenhouse Design and Management handout to each student. The teacher should lead students through each of the factors and considerations listed on the handout explaining how they influence decisions on designing and managing CEA systems. The teacher should encourage students to suggest other scenarios that they might think of that could limit (or enhance) the ability to grow crops or require certain types of CEA systems.

3.9.3 Activity - Greenhouse Production Challenge - 20 minutes

The teacher should hand out the Greenhouse Production Challenge handout and students should organize into their design teams. The teacher should explain that this activity tasks design teams to develop a growing plan to achieve goals given a set of project constraints. Teams will respond to two different scenarios that are requests from a school for items to use in the school's cafeteria. Teams' growing plans should include a list of what crops will be produced by the CEA system and what they cost to grow. Remember material costs and labor are two of the factors and considerations covered during the session introduction. Each team will have a design period of 5-7 minutes to develop their growing plans which will include a list of what and how many of each crop will be grown by each design team to achieve the goal. (Note: there are two different scenarios for teams to respond to; one without budget constraints and one with budget constraints).

3.9.4 Wrap-Up and STEAM Research Notebook Entry- 10 minutes

Following the Greenhouse Production Challenge, design teams should take measurements from the samples from the Light Chamber Experiment and Fertilizer Experiment and record results and observations in their STEAM Research Notebooks. Measurements should include the weight and soil temperature from each of the Light Chamber Experiment samples and the weight and plant height from each of the Fertilizer Experiment samples. Students can take note of any other visual observations as well. Following these measurements, if the samples appear to be drying out, students should add a small amount of water (~25-75 mL) to the sample.

These are the last measurements taken as part of these experiments. Design teams should report to the class measurements of each treatment sample and the teacher should graph results on a chart that is displayed in the classroom. The teacher should facilitate calculation of classroom mean, median, variance, and standard deviation using values reported by design teams during the past weeks of the experiments.   The teacher can lead a discussion with the class regarding what patterns and trends they see in the sample measurements collected.

- What do you think is happening?
- Why are there (or aren't there) differences between treatments?
- What about differences among samples from each design team for the SAME treatment?
- How does this help you think about your greenhouse prototype design?

The teacher should point out patterns such as clustering, outliers, positive or negative association, linear association, and nonlinear association. Each student should spend the final 5 minutes of the session completing a STEAM Research Notebook entry on reflections to these questions. Students should also include copies of their scratch paper calculations and growing plans from the greenhouse Production Budget Challenge in their STEAM Research Notebooks.

3.9.5 Deliverables for Session Nine

At the end of this session students should have completed the following:

- Worked in design teams to develop two growing plans to meet different goals and constraints
- Recorded weight and plant height measurements from the Fertilizer Experiment and weight and soil temperature from the Light Chamber Experiment. Results should be recorded in their STEAM Research Notebook.
- Completed a STEAM Research Notebook entry for the session

3.9.6 SESSION NINE RESOURCES

Factors and Considerations in Greenhouse Design and Management

Greenhouse Production Challenge

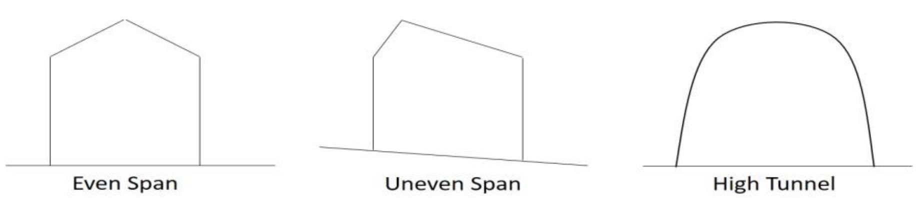
Factors and Considerations in Greenhouse Design and Management

Designing and creating controlled-environment agriculture (CEA) systems, such as greenhouses, requires careful planning and consideration in order to create systems that will be successful in optimizing plant growth. This handout lists a number of factors that should be considered when identifying project requirements and constraints and brainstorming potential designs and management plans.

Factors to Consider

- *Climate:* greenhouses are highly capable at controlling the internal climate within them to maximize crop production. However, designers and engineers still must consider climate conditions at their site. For example, if the area is very windy, then you probably don't want a tall structure that can be blown down easily. The length and coldness of winters may impact what you grow (cold-weather vs. warm-weather crops) or may suggest that some type of heating could be used to lengthen the growing season.
- *Topography/Aspect*: Is it flat or hilly at your site? Sloping sites may require more creative building plans (e.g. terracing) to construct a greenhouse but could also provide unique opportunities (e.g. harvesting water runoff). What direction does your site face? North facing slopes are generally cooler and wetter. South facing slopes are warmer and drier. This may impact the types of crops you grow (e.g. shade tolerant plants) or the material used in construction (e.g. transparent vs. non-transparent covering).
- *Water Supply*: Is water easily accessible? Plants require water, and a greenhouse must be able to supply enough water in a timely fashion whenever plants are at their peak water use. The period of peak water use is different for each crop but is generally around the period when plants flower. A general rule of thumb is that greenhouses will require 2 liters of water per day per square foot of growing area. Again, this number will vary by crop. If a public water supply or groundwater well are not available, then collecting runoff and surface water may be required.

- *Growing Material Costs*: How much fertilizer do my plants need? Some crops require a greater amount of nutrients to produce yield. If these crops are grown year after year, or in large volumes, an appropriate amount of fertilizer will need to be purchased.
- *Space Requirements*: How much space will my plants take up? Often space is one of the most limiting factors in greenhouse design and management. If a large leafy crop requires greater amounts of space to grow this may limit the overall potential yield of your greenhouse or limit available space for other crops. Some approaches get rather creative in using space, such as gardening with hanging baskets or vertical farming (https://en.wikipedia.org/wiki/Vertical_farming)
- *Available Labor*: Who is going to help you plant, water, fertilize, weed, harvest….? There are a number of tasks that are required to grow and take care of crop, and each step along the way will likely need some input of human labor to complete. How many workers will be available and at what time? Make sure peak periods of activity (i.e. planting, harvesting) are timed with some helping hands.
- *Greenhouse Shape*: The shape of the greenhouse structure can influence the amount of space available to grow plants (Figure 3.9.1). Structures with even roof widths and angle (i.e. even-span) help to maximize growing space underneath by having a large surface area on the ground and higher wall heights. This design can be modified by changing one of the roof widths/angles (uneven-span) to fit sites with sloping topography. High-tunnels are common in vegetable production and extremely cheap and easy to construct with a wide range of materials. However, the wall height is less with a high-tunnel design. A wide range of greenhouse shapes can be designed to fit site conditions. Figure 3.9.1: Greenhouse structure over varied space



-

Greenhouse Production Challenge

Materials Needed

- Scratch paper
- Calculator

Activity

In this activity your design team is tasked with developing a growing plan for a small greenhouse operation that is supplying a local school with fresh produce for student lunches. Growing plans will include a list of what and how many of each crop will be grown in your CEA system to meet the needs of the school. Requests from the school change based on what is on their menu. Your team have 5-7 minutes to come up with your recommended growing plan that meets a particular school request for their menu. Remember, as part of every design project it's important to first identify the overall goals and constraints of the request.

A listing of various crops and their characteristics are provided in Table 1. Use this information to develop the best possible growing plan to meet the request of the school. There may be more than one potential solution to the problem.

Table 1. Crop Characteristics

Crop	Yield (kg)/ m2	Material cost/m2	Labor cost/m2	Total production cost/m2	Sale cost/kg	Total potential revenue/kg
Bell Pepper	7.81	$ 0.14	$ 0.16	$ 0.30	$ 0.59	$ 0.29
Cucumber	6.10	$ 0.12	$ 0.19	$ 0.31	$ 0.57	$ 0.26
Tomato	14.16	$ 0.13	$ 0.24	$ 0.37	$ 0.73	$ 0.36
Green Beans	1.46	$ 0.02	$ 0.20	$ 0.22	$ 1.36	$ 1.14
Carrots	2.08	$ 0.01	$ 0.06	$ 0.07	$ 0.36	$ 0.29
Eggplant	1.59	$ 0.02	$ 0.07	$ 0.09	$ 0.64	$ 0.55
Salad Greens	0.37	$ 0.01	$ 0.01	$ 0.02	$ 2.27	$ 2.25
Peas	0.61	$ 0.03	$ 0.08	$ 0.11	$ 1.59	$ 1.48
Potato	1.46	$ 0.02	$ 0.05	$ 0.08	$ 0.57	$ 0.49
Sweet Potato	0.98	$ 0.01	$ 0.06	$ 0.07	$ 0.54	$ 0.48
Red Raspberries	0.73	$ 0.09	$ 0.04	$ 0.13	$ 3.63	$ 3.50
Strawberries	0.78	$ 0.01	$ 0.02	$ 0.03	$ 1.02	$ 0.99

Scenario 1: You currently have one $100m^2$ greenhouse that is available for production and a request from the school just came in. Please read the following request, identify the project goals and constraints, and develop a growing plan to send to the school.

> *"The last vegetables that we got from your greenhouse were excellent! The students loved them and I can assure you they didn't last long :) We are working on a new school menu and would like to include a salad as part of this. Ideally the salad would have a few vegetables that we can chop up and throw in with it...but no peppers please! Could you please send us a plan regarding what your greenhouse is able to provide? We would like as much produce as we can get! Thanks so much!"*

Scenario 2: You again have one $100m^2$ greenhouse available for production, but this year is shaping up to be a little more difficult. Money available for materials and labor are limited. We can spend a total of $20 to grow fruits and vegetables but would like our total revenue (Revenue = Sales - Production Cost) to be as high as possible. Another request from the school just came in. Please read the following request, identify the project goals and constraints, and develop a growing plan to send to the school.

> *"Boy oh boy, we just can't get enough of your sweet, fresh produce! We can't say how grateful we are to be able to get fresh, local fruits and vegetables for our students. For our next school lunch menu, we would like to have a mix of potatoes (sweet or regular), at least one stew vegetable (cucumber, carrots, peas), and tomatoes for soup. Also, if we could get one fruit (raspberries or strawberries) that would be excellent as well. We look forward to hearing from you!"*

3.10 SESSION TEN - Heat and Classroom Greenhouse Design Session I - 40 minutes

Students will briefly be introduced to heat as an environmental condition that is critical to greenhouse design. The concepts of radiation and transmittance, absorption, and convection will be presented as ways the sunlight's energy passes through greenhouse glass and warms the plants, soil, and other things inside the greenhouse. Students will return to this concept in Session Fifteen to test their greenhouse prototype's ability to transmit and absorb heat. Session Ten also provides students with design challenge specifications and constraints to be considered. During the activity, students will work individually to sketch greenhouse prototype solutions that will consist of a desktop size 50 x 50 centimeter greenhouse prototype.

3.10.1 Teacher Preparation, Session Ten

Teachers should assemble materials, duplicate handouts, and preview videos used in the session.

Teacher Materials:

Presentation on how greenhouse heating works (prepared by teacher)

Figure 1. greenhouse heated by solar radiation (Source: https://www.school-for-champions.com)

Figure 2. greenhouse remains warm (Source: https://www.school-for-champions.com)

Figure 3. Heating of greenhouse by solar radiation (Source: http://www.hydroponics-simplified.com)

Engineering Design Process (EDP)

Greenhouse sketch example 1 (Source: www.permies.com)

Greenhouse sketch example 2 (Source: http://www.greenhousexpress.com)

Digital Resources:

Internet access

Student Materials:

STEAM Research Notebook

Pen or Pencils (multiple colors)

Student greenhouse prototype materials (1 per design team):

Structural Frame must be made of wood, metal, or plastic (pvc pipes)

Acrylic or Plexiglas or Plastic for wall coverings

Hot glue gun or glue sticks, expandable glue (e.g. Gorilla Glue), tape, and nails

Hammer, saws, stapler

Soil and plants

Thermometer

Tools to share (saws, hammers, etc.)

Handouts:

Greenhouse Challenge Criteria Sheet

Table 3.10 Explicit Knowledge Required for Session Ten

Core Area	Knowledge Required	Supports for Student Learning
Science	*Nature of scientific inquiry.* Students should understand that scientists ask questions and use observations and measurements through thoughtfully designed inquiries to collect data about their questions. Scientists keep records of the data they collect and their ideas in scientific notebooks.	Teachers will review the purpose of the notebook and its format with students and will provide examples of scientists and their work.
	Students should understand that the key to engineering is the design. Engineering uses science and technology to solve practical problems by designing solutions and manufacturing products and processes.	Teacher introduces the engineering design process (EDP) to students, providing an opportunity to discuss the process of engineering.
Art	Students should be able to produce artistic products that demonstrate consideration of elements of line, color, shape, texture, impasto, and orientation (landscape and portrait). Students will apply knowledge of art as they begin to sketch on how their greenhouse prototype will be artistically represented.	The teacher will provide time for students to make their STEAM Research Notebook entries.

Mathematics	Students should be able to use ratio reasoning to manipulate and convert measurement units as part of a model sketch.	The teacher will provide support and answer student questions during sketching activities.
Language Arts	Students should be able to write narrative text about their experiences using effective technique, descriptive details, and clear event sequences. Students should understand the value of reflection and the habit of summing up their learning.	A writing rubric is included in the STEAM Research Notebook for students to use to self-assess their writing. The teacher will provide models of explanatory writing and science notebooks using books illustrating science notebooks such as the one recommended in Session 1.
Social Studies	Students should understand that daily life is influenced by agriculture, industry and natural resources in different communities. Students should understand the needs of communities related to access to food.	Teachers will continue to discuss with student teams the role that agriculture plays in society.

3.10.2 Introduction - 15 minutes

The teacher will present a presentation on how a greenhouse regulates temperature, and inform students that today will be the start of their greenhouse prototype design and build. Students should know that a greenhouse is a building that is heated with solar radiation; however, how it stays insulated to prevent loss from convection, conduction and radiation, such that it can stay warm without external heating even during cold days of winter. Tell students that greenhouses operate on four principals: radiation, transmittance, absorption and convection. Through using greenhouses, people are able to harvest energy from the sun and use it to maintain a warm and humid indoor environment conducive for plants to grow. Using images (Figures 1, 2, and 3), students can visualize the path of solar radiation heating the greenhouse. Introduce the following concepts:

- **Radiation and Transmittance** — Almost all the heat within a greenhouse comes directly from the sun through radiation. This energy is radiated through the Earth's atmosphere and transmitted through glass (or other transparent material) to the interior of the greenhouse.

- **Absorption** — Once energy from the sun reaches the inside of the greenhouse, it must be absorbed. It helps to have a surface that absorbs almost all the energy that hits it (for example, something dark; soil works well). Whatever is inside the greenhouse continues to absorb this energy.
- **Convection** — Once energy is absorbed within the greenhouse, heat is transferred throughout the space through convection. Cooler air falls to the bottom and gets heated up by the absorbing surface, and the process repeats. Because convection is the way the rest of the greenhouse gets heated, it is important to tightly seal the entire structure. Even opening the door for a short period of time can significantly reduce the indoor temperature.

The result of this process is an indoor environment much warmer than normally achievable without a greenhouse. If the temperature gets too high, it is easy to adjust it by opening a window or door to let out some heat.

Explain to students that greenhouse design can be modified to account for specific temperature needs. While changing the slope of the walls and roof does not change the amount of radiation entering, changing the dimensions does. A larger surface area leads to a larger amount of transmitted radiation. To harness all this radiation, a large absorptive surface is also required. For a higher-heat greenhouse, the floor surface area should be maximized while the volume of the overall greenhouse should be minimized (to allow for less space to be heated with the same amount of radiation). Of course, engineers must remain within certain constraints while designing them this way. For a larger capacity, a greenhouse simply needs more volume with a considerable amount of radiation still being transmitted. greenhouses should be designed to optimally suit the specific needs of the user, so engineers must understand any necessary design modifications. The teacher should inform students that when they test their greenhouse prototype, they will account for their new structure's ability to absorb and regulate warm temperatures. The teacher should now transition topics to the application of the engineering design process (EDP).

Over the last several sessions, students have been building background knowledge and experience with the basics of earth, human, and food system interactions. Show students the engineering design process image (EDP Image) and briefly review major concepts learned up to this point and how students have been applying different aspects of the EDP (i.e. ask, imagine, plan, etc.). Now it is time for students to use what they have learned and apply it to their Classroom Greenhouse Design Challenge. Over the remaining sessions students will work individually, with their design team, and as a class to create, test, improve, and share in the development of functional greenhouse prototypes that will compete for the winning design for the school greenhouse.

3.10.3 Activity - Classroom Greenhouse Design Session I - 20 minutes

1. Review the Scenario Prompt with students and Begin the Challenge:

   The school is seeking competitive bids for a new, school greenhouse that will service as a source for fresh local produce as well as a learning laboratory. Interested companies are invited to submit proposals to the school for designing and building a greenhouse that will meet the following criteria.
2. Pass out the Greenhouse Challenge Criteria Sheets and review Criteria, Objectives, and Design Constraints for challenge.
3. **ASK Stage.** The first stage of the design process is asking, “What is the problem or challenge and what are we going to do?”

   Your team has been asked to create a school greenhouse that will grow fresh produce and serve as a learning laboratory to the school. Your team will have the remainder of this class period to sketch the prototype, then one session (Session Eleven) to draw it in a program called Tinkercad (all drawings must be drawn to scale 50 x 50 cm), one session to regroup and brainstorm with your team to develop the best design and plan your tasks (Session Twelve), two sessions to build the model (Sessions Thirteen - Fourteen), and one session to test your greenhouse prototype’s temperature capacity (Session Fifteen). Because this is a business venture, you will need to submit a budget along with a growing plan and documentation of your testing. Your design team (Company) will give a 10-minute presentation to 'sell' their greenhouse prototype to the class.

4. What are the design constraints? The greenhouse prototype MUST be built with the following materials (show the students the materials they will have to work with to complete the challenge):
    - Structural Frame must be made of wood, metal, or plastic (pvc pipes)
    - Acrylic or Plexiglas or Plastic for wall coverings
    - Hot glue gun or glue sticks, expandable glue (e.g. Gorilla Glue), tape, and nails
    - Hammer, saws, stapler
    - Soil and plants
    - Thermometer
    - Tools to share (saws, hammers, etc.)

    The teacher should have materials available in the classroom for students to investigate. Give students time to touch, look, and manipulate materials before they begin the sketching process.

5. **IMAGINE AND PLAN Stage**

    What are some possible solutions? Gather the materials that you must work with to test and play. Draw a sketch of your design, and list the materials you will need. What steps will be needed to build? How much will it cost?

    In their STEAM Research Notebooks, each student should provide a sketch of their greenhouse prototype. Use an appropriate scale in your sketch to ensure the floor plan dimensions fits a 50 cm x 50 cm model.

For the remainder of Session Ten, students should have time to begin sketching their prototype. Encourage students to take their STEAM Research Notebooks home to continue sketching. Designers make many sketches over time before creating the sketch they want to pursue.

3.10.4 Wrap-Up - 5 minutes

Discuss with students any questions or concerns about the challenge to make sure students are on path to the intended objectives and outcomes. Prompt them with some questions and statements:

- What are your ideas to make the greenhouse?
- Remember the dimensions of the greenhouse prototype floor must be 50 cm x 50 cm.
- Are you running into any challenges?
- Use your notebook space to sketch.
- Explore and experiment with the building materials for the model.
- Add information about materials to the design solution plans.
- Students will draw their prototype idea.

3.10.5 Deliverables for Session 10

At the end of the session, students should have completed the following:

- Greenhouse sketches in STEAM Research Notebooks

3.10.6 SESSION TEN RESOURCES

Figure 3.10.1. Greenhouse heated by solar radiation (Source: https://www.school-for-champions.com)

Figure 3.10.2. Greenhouse remains warm (Source: https://www.school-for-champions.com)

Figure 3.10.3. Heating of greenhouse by solar radiation (Source: http://www.hydroponics-simplified.com)

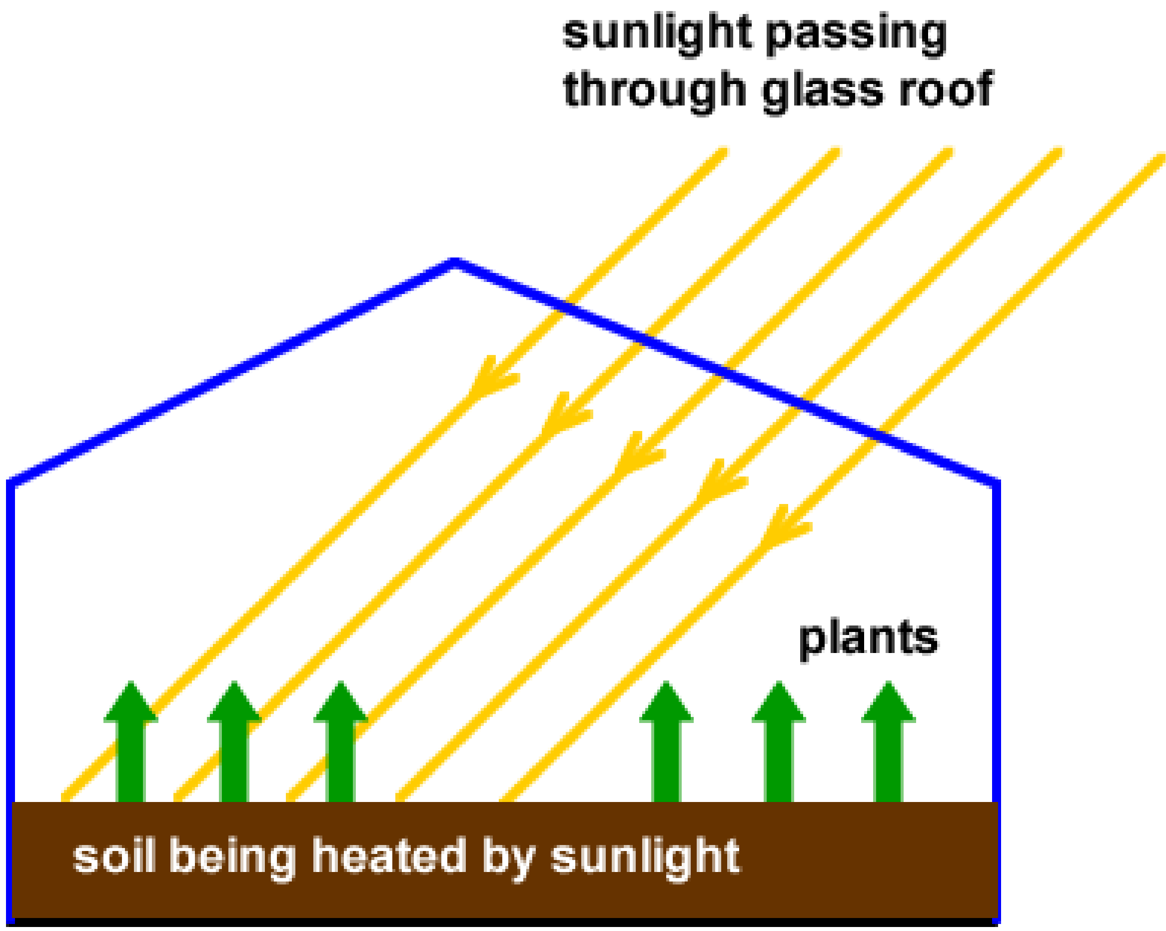
Engineering Design Process

Greenhouse sketch example 1 (Source: www.permies.com)

Greenhouse sketch example 2 (Source: http://www.greenhousexpress.com)

Greenhouse Challenge Criteria Sheet

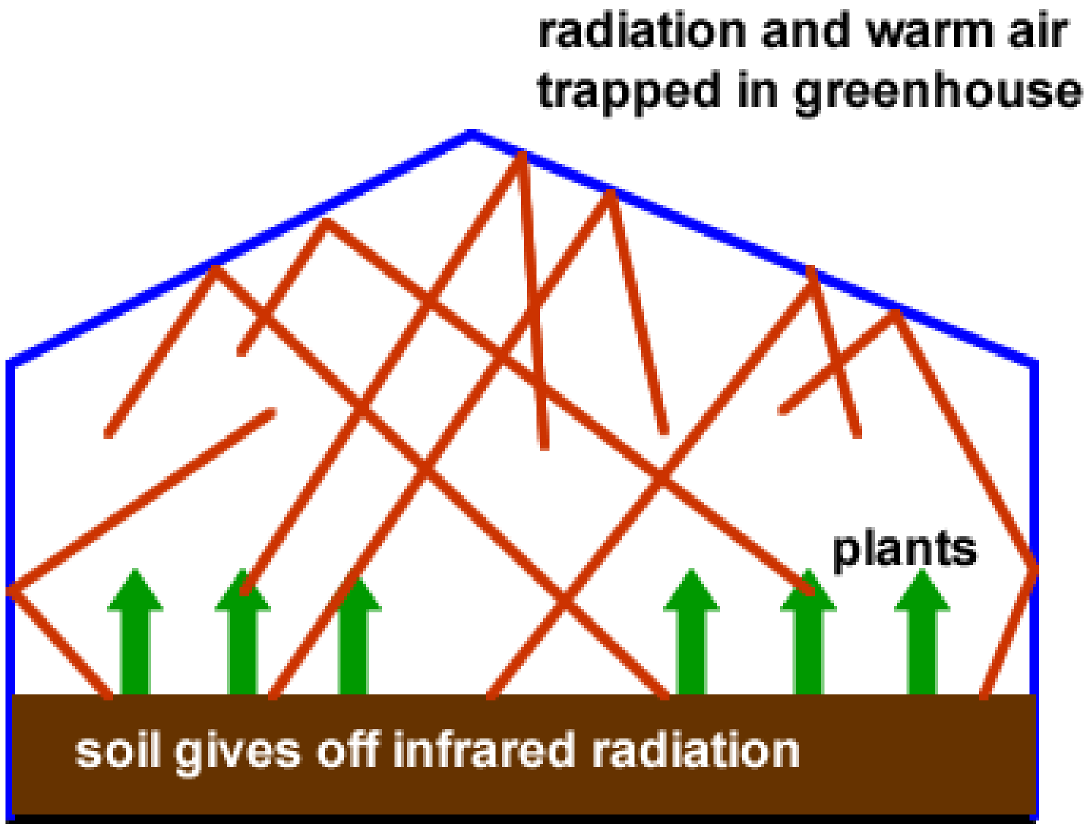
Figure 3.10.1. Greenhouse heated by solar radiation



Greenhouse heated by solar radiation

(Source: https://www.school-for-champions.com)

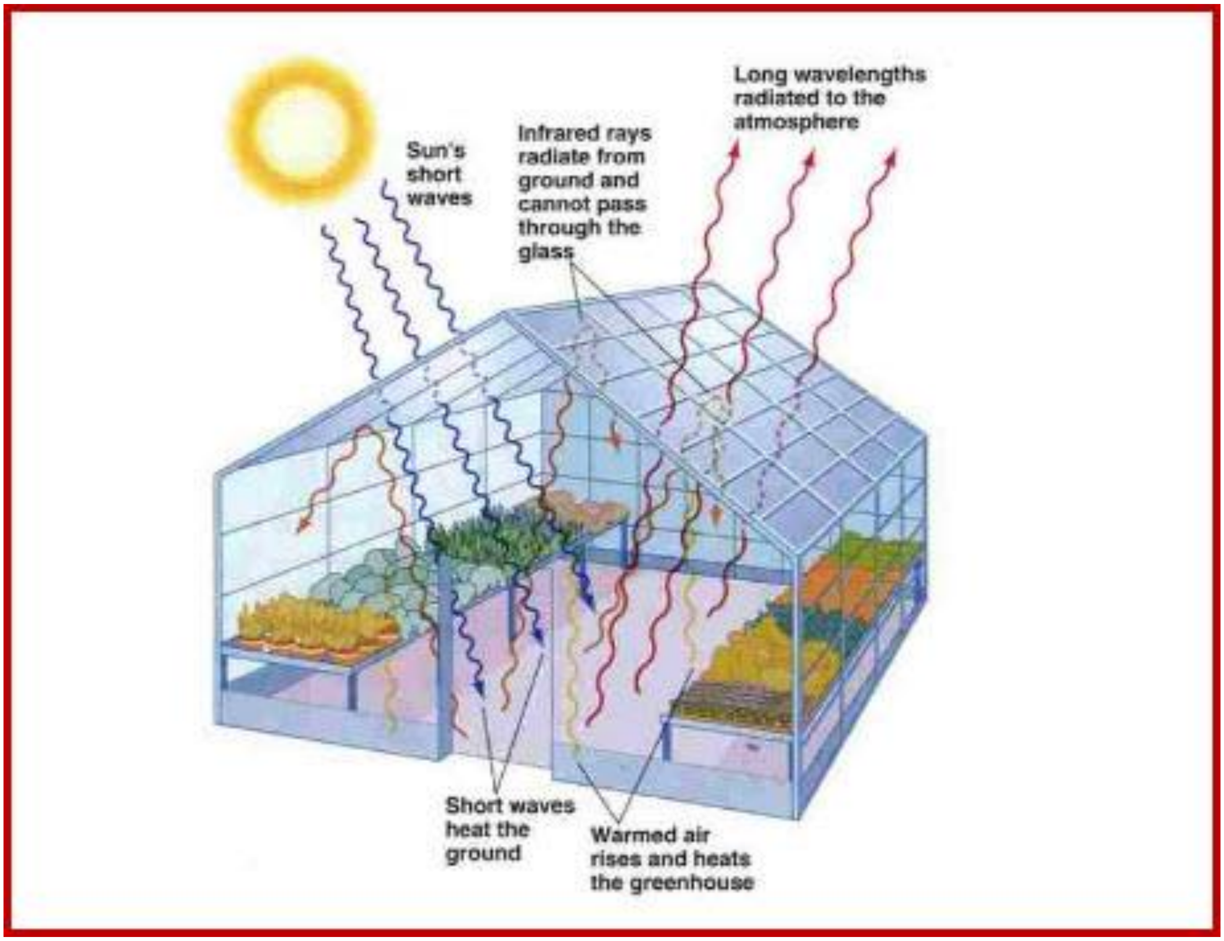
Figure 3.10.2. Greenhouse remains warm



Greenhouse remains warm

(Source: https://www.school-for-champions.com)

Figure 3.10.3. Heating of greenhouse by solar radiation



Heating of greenhouse by solar radiation

(Source: http://solarinsolation.org/tag/garden-greenhouses/)

Figure 3.10.4: Engineering Design Process Chart

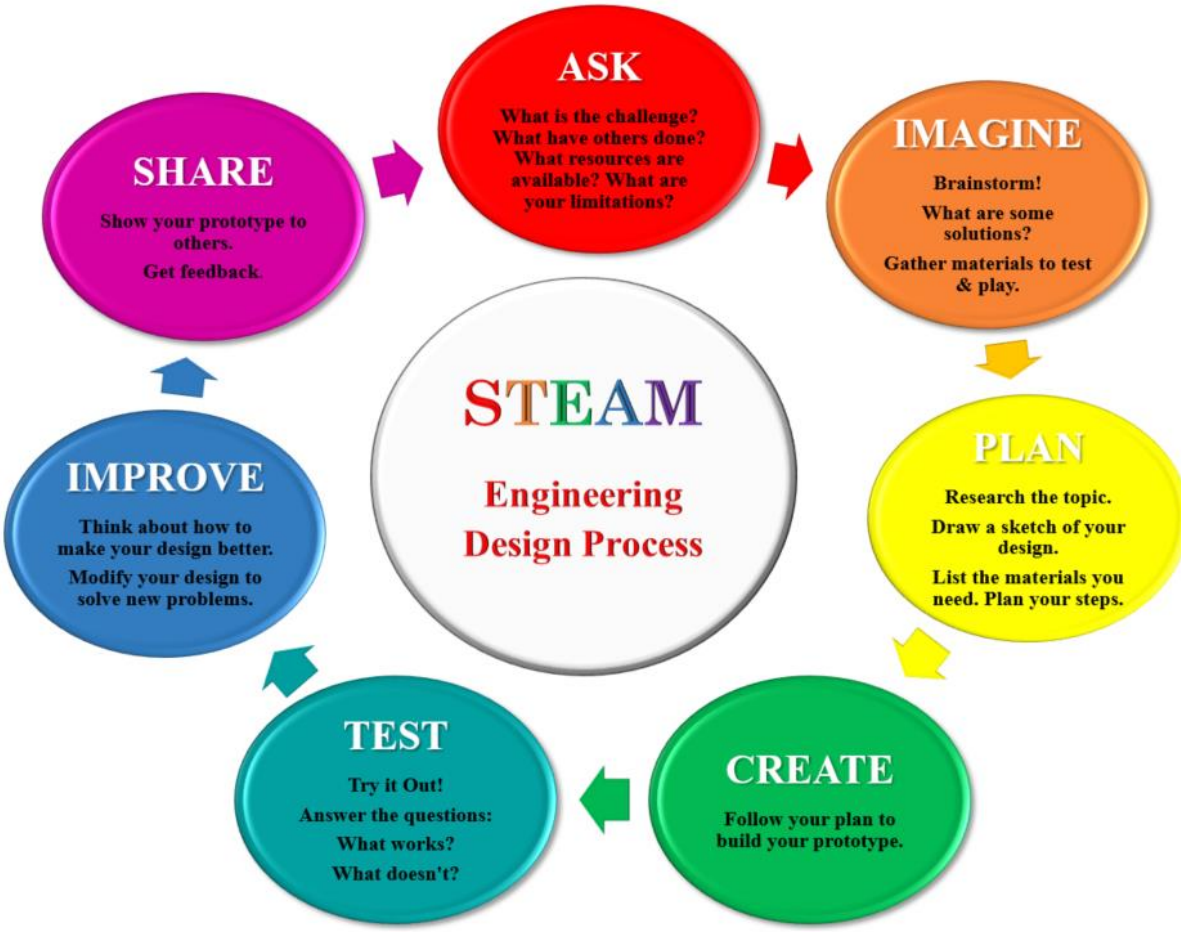
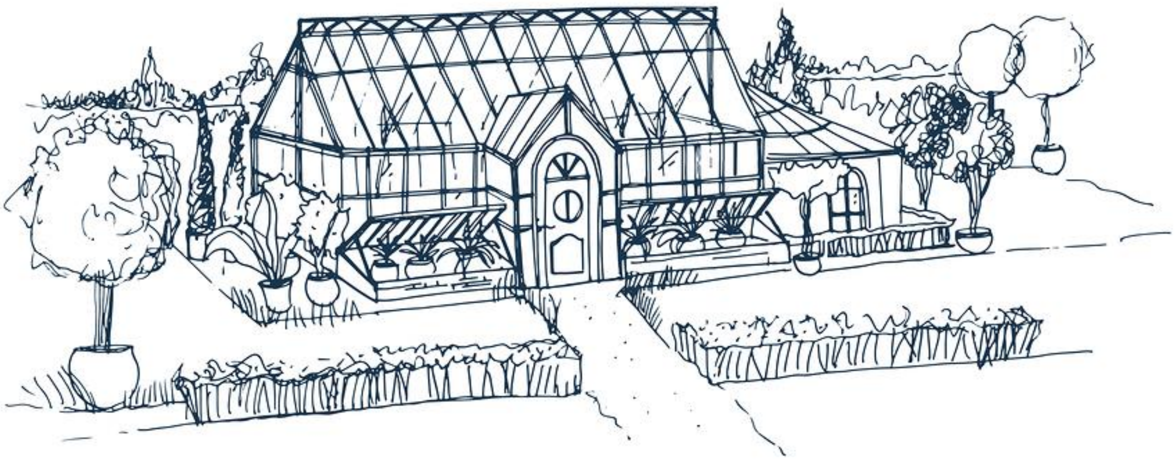


Figure 3.10.5: Greenhouse sketch example



Greenhouse Challenge Criteria

Scenario: The school is seeking competitive bids for a new, school greenhouse that will service as a source for fresh local produce as well as a learning laboratory. Interested companies are invited to submit proposals to the school for designing and building a greenhouse that will meet the following criteria.

Criteria and Objectives of Greenhouse Design Challenge:

Design and draw a 50 x 50 cm greenhouse concept model to scale with your design team.

All your sketch designs must be documented in your STEAM notebook.

You must develop a 3-Dimensional greenhouse prototype sketch in Tinkercad to scale (include dimensional information this prototypes to be scaled up to a larger classroom greenhouse).

Using your 3-Dimensional sketch, successfully build a 50 x 50 cm foot greenhouse prototype model.

You must develop a materials budget and stay within the budget allowed by teacher.

You must successfully test, record, and graph the model greenhouse indoor and outdoor temperatures over time.

Design teams will develop and give a 10-minute presentation to sell their classroom greenhouse prototype to the class (Session 17). The presentation must include (CHECKLIST & Project Timeline below):

1. Sketches (Session 10)
2. 3-D Tinkercad drawings to scale (Sessions 11 - 14)
3. Approved Subcontractor List & Materials Budget (Sessions 12 - 14)
4. Greenhouse prototype model (Session 13 - 14)
5. Results from temperature experiments (Session 15)
6. A Proposed Growing Plan for greenhouse (Session 15 & 16)
7. Ideas for improving the greenhouse in the future (Session 15 & 16)
8. Design Team Business Name and Logo
9. Greenhouse Design Name

Design Constraints:
Greenhouse prototype must be built with the following materials:

- Structural Frame must be made of wood, metal, or plastic (PVC pipes)
- Acrylic or Plexiglas or Plastic for wall coverings
- Hot glue gun or glue sticks, expandable glue (e.g. Gorilla Glue), tape, and nails
- Hammer, saws, stapler
- Soil and plants
- Thermometer

3.11 SESSION ELEVEN - Classroom Greenhouse Prototype Design Session II - 40 minutes

Students will review the Classroom Greenhouse Design Challenge criteria, objectives, and constraints. The teacher should ensure students are on the right path to meeting project goals while considering which building materials students might use and how much the greenhouse prototype will cost. Students will review the properties of heat transfer and apply their understanding to their greenhouse prototype sketch. The majority of Session Eleven should be spent on the Imagine and Planning stage of the EDP as individual students complete their sketches and begin transferring and drawing sketch ideas on Tinkercad's workplane to produce a 3-D model image of their greenhouse prototype.

3.11.1 Teacher Preparation, Session Eleven

Teachers should assemble materials and duplicate handouts used in the session. It is up to the teacher to make decisions on the classroom greenhouse contraints. School resources may vary and the Approved Subcontractor List & Materials Budget is a starting reference point. For schools with unlimited budgets the goal could be make the most, unlimited innovative design. For schools with more modest means, the least expensive economic design may be the goal. Preparation ahead of time to determine the goals of the teacher that meet the resources available should be considered and incorportated into planning ahead of time.

Teacher Materials:

Figure 3.11.1. Tinkercad scaled greenhouse example 1

Figure 3.11.2. Tinkercad scaled greenhouse and platform example 2

Figure 3.11.3. Tinkercad scaled greenhouse example 3

Digital Resources:

Tinkercad: https://www.tinkercad.com/learn/

Internet access

Student Materials:

STEAM Research Notebook

Pen or Pencils (multiple colors)

Student greenhouse prototype materials (display prominently):

Structural Frame must be made of wood, metal, or plastic (pvc pipes)

Acrylic or Plexiglas or Plastic for wall coverings

Hot glue gun or glue sticks, expandable glue (e.g. Gorilla Glue), tape, and nails

Hammer, saws, stapler

Soil and plants

Thermometer

Tools to share (saws, hammers, etc.)

Handouts:

Greenhouse Challenge Criteria Sheet (from Session Ten)

Approved Subcontractor List & Materials Budget

Table 3.11 Explicit Knowledge Required for Session Eleven

Core Area	Knowledge Required	Supports for Student Learning
Science	*Nature of scientific inquiry.* Students should understand that scientists ask questions and use observations and measurements through thoughtfully designed inquiries to collect data about their questions. Scientists keep records of the data they collect and their ideas in scientific notebooks.	Teachers will review the purpose of the notebook and its format with students and will provide examples of scientists and their work.
Mathematics	Students should be able to generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.	Students will draw comparisons between different types of growing systems that were designed to provide particular solutions with a limited set of available materials.

Mathematics	Students should understand that a budget is a plan to help people make personal economic decisions for the present and future and to become more financially responsible. Students will consider the material costs for building a greenhouse as they design their prototype	The teacher will facilitate student conversations as they discuss potential challenges, rewards, and maintenance items associated with building the greenhouse with different materials.
	Students should be able to use their knowledge of shapes and heat transfer to create their greenhouse design.	The teacher will provide support to the student teams to clarify the difference in shapes and what that means to energy transfer as needed.
	Students should be able to use variables to represent numbers and write expressions when solving a real-world or mathematical problem	The teacher will provide support and answer student questions during sketching activities.
	Students should be able to calculate the area and volume of circles, triangles, and polygons.	
	Students should be able to use ratio reasoning to manipulate and convert measurement units as part of a model sketch.	
Art	Students should be able to translate artistic products that demonstrate consideration of elements of line, color, shape, texture, impasto, and orientation (landscape and portrait) into a Computer-Aided Design. Students will apply knowledge of art as they begin to sketch on how their greenhouse prototypes will be artistically represented.	The teacher will provide learning supports as the students navigate the Tinkercad application on the computer.
Language Arts	Students should be able to use communication skills including letters, words, and sentences to communicate their ideas.	Teachers will support students to articulate their ideas.
Technology	Students should be able to use technology as a tool to design and communicate ideas. Students will use computers to draw and scale 3-D images of their imagined greenhouse prototypes.	The teacher will assist students in need with interactive learning modules to complete the task in this session.

3.11.2 Introduction - 5 minutes

The teacher should facilitate a discussion, starting with a review of the Greenhouse Design Challenge criteria, objectives, and constraints. The teacher should begin to apply this conversation specifically to the materials the students will be using to build. At this time, the teacher should introduce the Approved Subcontractor List & Materials Budget handout. Students can begin to review the cost of different materials. Students should make comparisons between building material items. Which building frame supplies are strongest? Is a steel frame the most economical solution for this project? Discussion should include considerations of design, cost, heat transfer, feasibility in building, structural integrity, etc.
For example, the teacher should ask students about how different materials (Plexiglass, Acrylic or Plastic) might have a greater or lesser ability to transfer heat into the greenhouse? What kind of heat transfer does a greenhouse use to gain heat? How is it able to do this? (the greenhouse gains heat through solar radiation; it is able to do this because radiation does not require a medium and can easily be transmitted through transparent or nearly transparent materials [such as plastic].) What kind of heat transfer does the greenhouse prevent (between the inside and outside)? How does this help the greenhouse operate? (the greenhouse prevents convection heat transfer between the indoor and outdoor air. This allows the indoor air to be heated up while keeping it from exchanging with the cooler outdoor air. Because the greenhouse is sealed up, it only loses heat through conduction.).

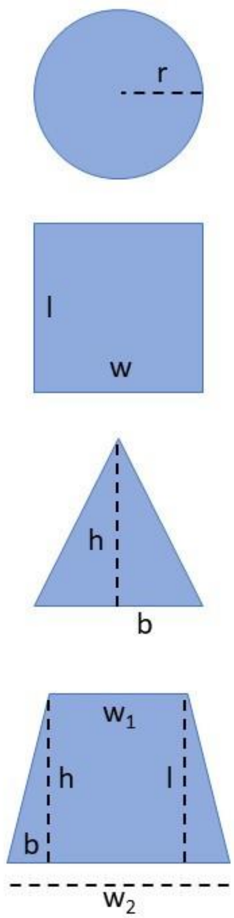
Students should finish their hand sketches with these considerations in mind before they begin Tinkercad drawings.

3.11.3 Activity - Classroom Greenhouse Prototype Design Session II - 30 minutes

1. Each individual student should finish their greenhouse prototype sketch in their STEAM Research Notebooks. Students should have started sketches in Session Ten. Remind students that their greenhouse prototype must fit on a 50 cm x 50 cm base and a scale should be included on their sketch.

2. Students should indicate the different types of heat transfer on their greenhouse prototype sketches, as well as list the different building materials they intend to use.
3. Students should estimate the total growing area that is provided by their greenhouse prototype sketch using surface area calculations for basic geometric shapes (equations shown below). Students should write an equation which shows how they calculated the total growing surface area for their greenhouse prototype. This equation may be included next to their scale notation.

Figure 3.11.1: Geometric Surface Area Equations



$$A = \pi r^2$$

$$A = l\ x\ w$$

$$A = \frac{b\ x\ h}{2}$$

$$A = area\ of\ 2\ triangles + area\ of\ 1\ rectangle;$$
$$where\ h = l\ and\ w_2 = w_1 + 2b$$

4. Have students pair-up to share, review, and provide feedback on the sketches.
5. Before logging into Tinkercad, the teacher should check everyone’s progress and comprehension to ensure students are on the right path.

6. (Optional): Students login to Tinkercad and complete a short tutorial with learning modules on Tinkercad (5-10 minutes).
7. Students draw greenhouse prototype in Tinkercad, ensuring the floor plan is 50 x 50 centimeters using the ruler object to scale the images. See Figures 1-3 for example sketches with dimensions noted.

3.11.4 Wrap-Up - 5 minutes

Discuss with students any questions or concerns about the challenge to make sure students are on path to the intended objectives and outcomes. Prompt them with some questions and statements:

- Are their ideas to make the greenhouse looking accurate in Tinkercad?
- What building materials are they planning to use to build their model?
- Add information about materials and cost to the design solution plans.
- Remember the dimensions of the greenhouse prototype floor must be 50 x 50 cm.
- Are you running into any challenges?
- Use your notebook space to sketch, capture thoughts, and plan ideas

3.11.5 Deliverables for Session Eleven

At the end of the session, student individuals should have completed the following:

- Final sketches in STEAM Research Notebooks
- Initial drawings in Tinkercad

3.11.6 SESSION ELEVEN RESOURCES

Figure 1. Tinkercad scaled greenhouse example 1

Figure 2. Tinkercad scaled greenhouse and platform example 2

Figure 3. Tinkercad scaled greenhouse example 3

Approved Subcontractor List & Materials Budget

Greenhouse Challenge Criteria Sheet (from Session Ten)

Figure 3.11.2: Tinkercad scaled greenhouse example 1

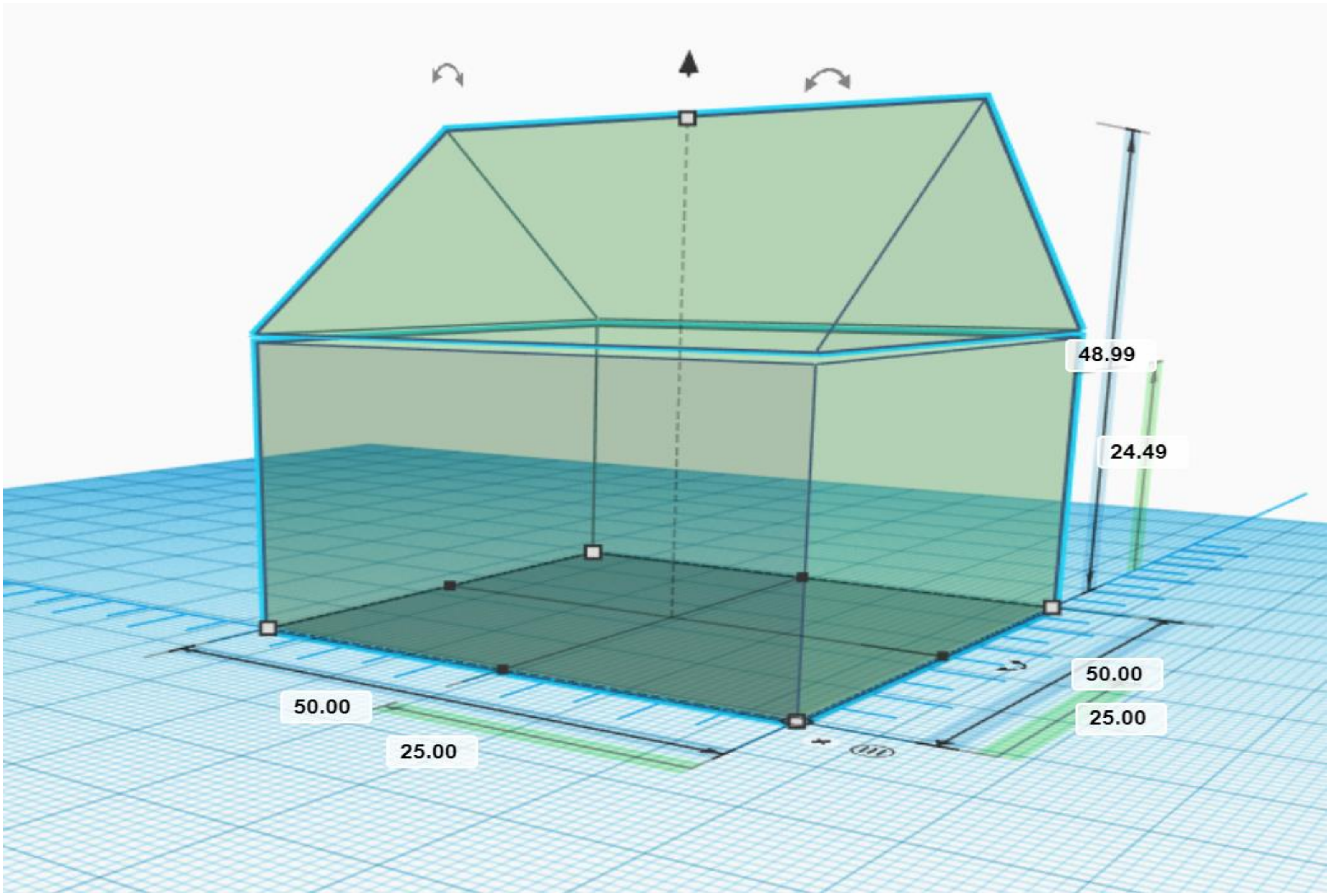


Figure 3.11.3. Tinkercad scaled greenhouse and platform example 2

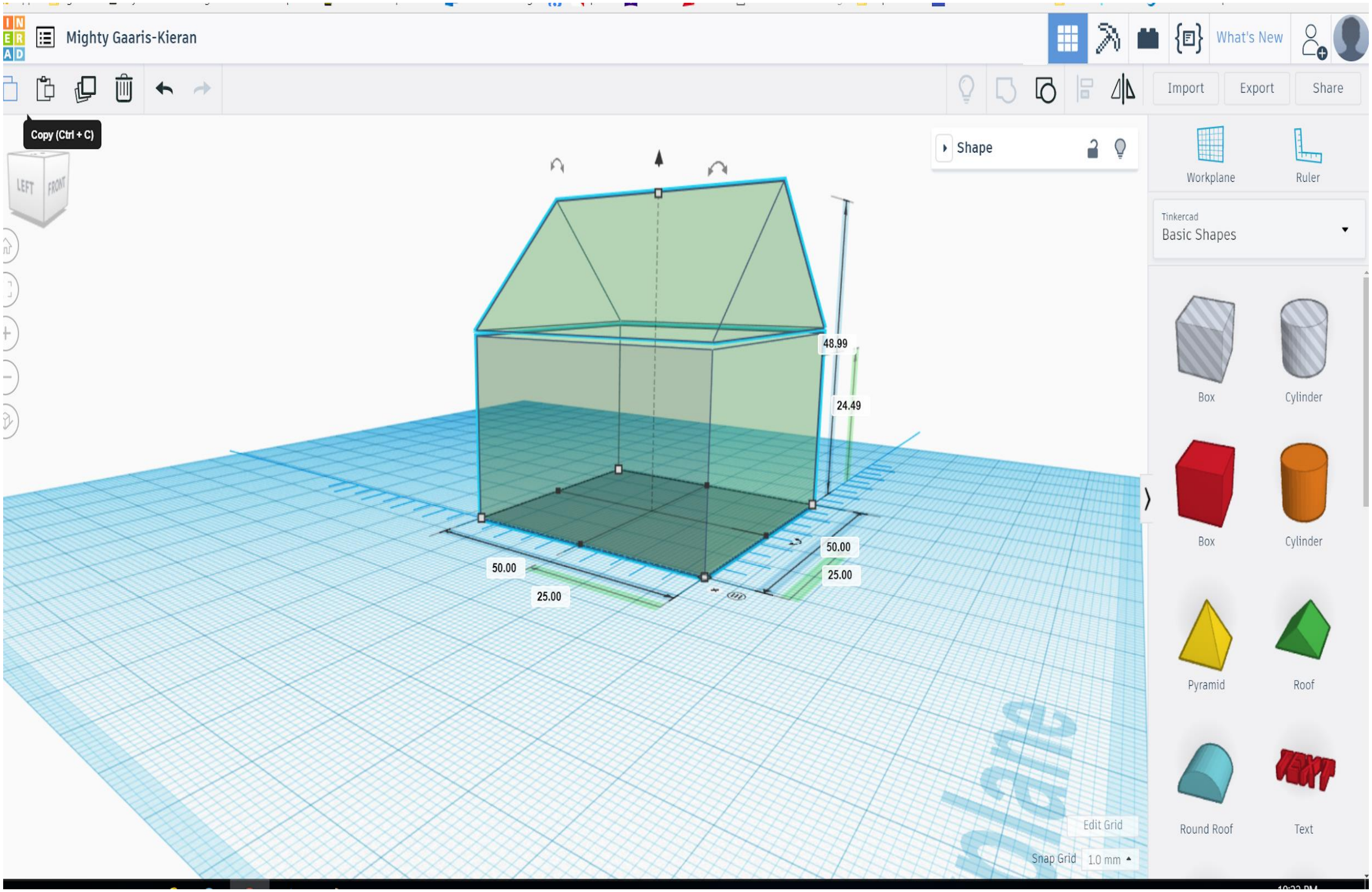
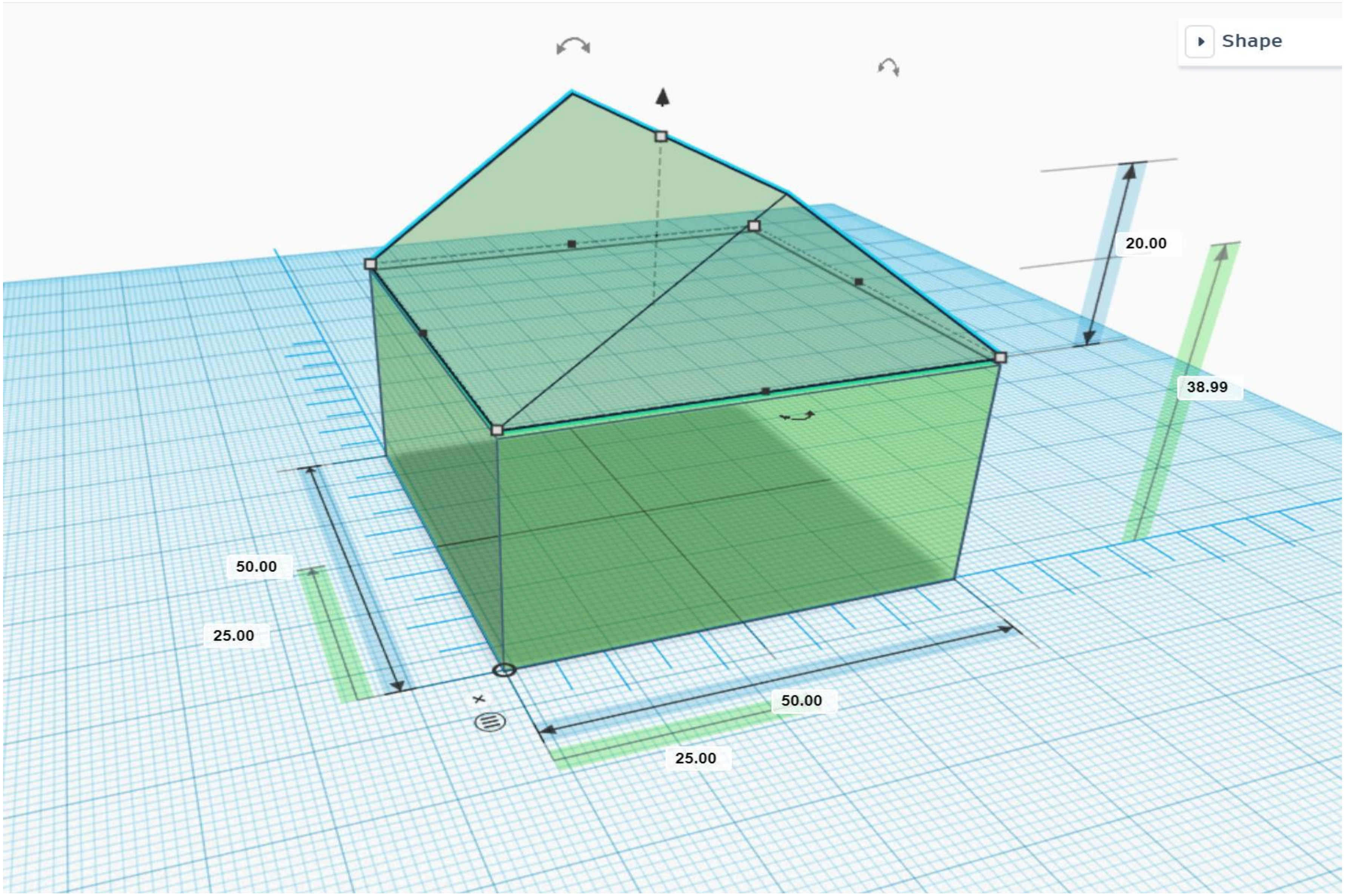


Figure 3.11.4. Tinkercad scaled greenhouse example 3



Approved Subcontractor List & Materials Budget

Required Service Purchases (Unlimited Uses)			
Company	**Item**	**Market Cost**	**Actual Budget**
Keep it Cool Instrumentation	Thermometer	$10	
Sustainable Schoolyard	Rental space for hosting greenhouse on schoolyard	$15 per square meter	

Building Materials				
Company	**Item**	**Market Cost**	**Quantity**	**Actual Budget**
International Framing Supply Company	Wood boards – per meter	$3		
	Steel supports - per meter	$15		
	PVC pipe – per meter	$6		
	Cardboard – per meter	FREE		
International Keep-It-Together Company	Hot glue gun, glue sticks – per stick	$0.25		
	Heavy Duty Duct Tape – per roll	$8		
	Expandable Glue – per container	$5		
	Nails – per 1 lb box	$1		
Let the Sun Shine Through Solutions	Greenhouse Film - per square meter	$0.30		
	Acrylic – per square meter	$18		
	Plexiglass – per square meter	$30		
			Total Budget	
			Total Adjusted Budget	

3.12 SESSION TWELVE - Classroom Greenhouse Prototype Design Session III - 40 minutes

During Session Twelve, design teams brainstorm and make decisions about their ultimate greenhouse prototype design. Each student will have an opportunity to share their sketches and Tinkercad drawings with their team. Design teams will compare designs and either pick their favorite or create a new design together. The design team will construct their Design Team Action Plan and delegate people to execute design challenge tasks.

3.12.1 Teacher Preparation, Session Twelve

Teachers should assemble materials, duplicate handouts, and preview videos used in the session. The teacher should spend ample time during the lesson checking in with design teams to ensure they are on task and target for delegating roles to associated tasks.

Teacher Materials:

Engineering Design Process resources

Digital Resources:

Tinkercad: https://www.tinkercad.com/learn/

Internet access

Student Materials:

STEAM Research Notebook

Pen or Pencils (multiple colors)

Student greenhouse prototype materials (1 per team):

Structural Frame must be made of wood, metal, or plastic (pvc pipes)

Acrylic or Plexiglas or Plastic for wall coverings

Hot glue gun or glue sticks, expandable glue (e.g. Gorilla Glue), tape, and nails

Hammer, saws, stapler

Soil and plants

Thermometer

Tools to share (saws, hammers, etc.)

Handouts:

Greenhouse Challenge Criteria Sheet (from Session Ten)

Approved Subcontractor List & Materials Budget (from Session Eleven)

Design Team Action Plan

Table 3.12 Explicit Knowledge Required for Session Twelve

Core Area	Knowledge Required	Supports for Student Learning
Science	*Nature of scientific inquiry.* Students should understand that scientists ask questions and use observations and measurements through thoughtfully designed inquiries to collect data about their questions. Scientists keep records of the data they collect and their ideas in scientific notebooks.	Teachers will review the purpose of the notebook and its format with students and will provide examples of scientists and their work.
	Students should be able to generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.	Students will draw comparisons between different types of growing systems that were designed to provide particular solutions with a limited set of available materials.
	Students should understand that the key to engineering is the design. Engineering uses science and technology to solve practical problems by designing solutions and manufacturing products and processes.	Teacher reviews the engineering design process (EDP) with students.
Mathematics	Students should understand that a budget is a plan to help people make personal economic decisions for the present and future and to become more financially responsible. Students will consider the material costs for building a greenhouse as they select their prototype	The teacher will facilitate student conversations as they discuss potential challenges, rewards, and maintenance items associated with building the greenhouse with different materials.

	Students should be able to calculate the area and volume of circles, triangles, and polygons.	The teacher will provide support and answer student questions during sketching activities.
	Students should be able to use ratio reasoning to manipulate and convert measurement units as part of a model sketch.	
	Data collection and analysis Students should be able to use appropriate methods (such as counting, measurement, experiment, etc.) to collect data according to simple questions, and record the data.	Students use the Design Team Action Plan handouts to guide their data collection about their peer's greenhouse designs.
Science/ Language Arts	Students should understand that research is a necessary component of scientific inquiry and engineering design. Students should understand that research involves investigating how other people have solved similar problems or investigating products or devices designed with goals similar to their design goals. Students should understand how to take brief notes on their observations and sort evidence into categories.	Students share ideas about what makes a good greenhouse as an introduction to their research. The teacher can introduce the term *research* and communicate to students that research is important in product development in order to understand what is attractive to consumers and to avoid duplicating products that are already in production.
Social Studies/21st Century Skills	Students should understand that people often work in teams to solve problems. Students should understand that communicating clearly with team members is important for successful teamwork. Students should understand that listening to others' ideas and sharing their own ideas respectfully is important for successful teamwork.	Students begin to work in teams in this session and will continue teamwork throughout the unit, practicing and developing teamwork skills in each session. If students are new to working in teams, the teacher can prompt the class to develop a list of guidelines for good teamwork that includes such points as listening to others, being respectful, sharing ideas, being accountable for individual work, etc.

3.12.2 Introduction - 5 minutes

The teacher should review with the class the Greenhouse Design Challenge criteria, objectives, and constraints. Ask for students' questions now that they have finished their first round of sketches and Tinkercad drawings. Note that engineers are always checking back in on the Engineering Design Process, asking questions to their clients for clarification to ensure they are meeting project goals and objectives. Students have been working independently for the majority of the last two sessions, and today they will be joining their design teams to share and decide on the best ideas for their team's greenhouse prototype. Only one greenhouse prototype model will be built per group although everyone's ideas should be considered when contributing to the final design. As a team, the students will 'sell' their greenhouse prototype to the class during Session Seventeen. After design teams decide on their greenhouse prototype design, students will be given the Design Team Action Plan. Everyone's full participation and focus is critical to meet the demands of the project timeline (see Greenhouse Challenge Criteria handout). The Design Team Action Plan MUST be completed by the end of today's session.

3.12.3 Activity - Classroom Greenhouse Prototype Design Session III - 30 minutes

1. Have the students divide into design teams and discuss the following:
    - What are their best ideas to make the greenhouse prototype?
    - Students should use notebook and Tinkercad to share their ideas.
    - What building materials will work best for each student's design solution and why?
    - Which greenhouse prototype design could grow the most food? Hold the most heat?
    - Which greenhouse prototype is most economical? Scientific? Creative? Fun?
2. As a team, students will brainstorm and discuss each of the team members' designs. The design teams should prioritize which characteristics of the greenhouse prototype are most important to their team. Have students write down these characteristics in their STEAM Research Notebooks.
3. After each design team member has presented their individual designs, together, the team will sketch a JOINT greenhouse prototype. This will be the greenhouse prototype the team builds

(during Sessions Thirteen & Fourteen). Students should each have a sketch of the team design in their STEAM Research Notebooks.

4. Design Teams should next be given the Design Team Action Plan. Students must complete this form by the end of today's session in order to begin building during the next session. The teacher should help facilitate and make sure project tasks are delegate equally. Student's should use the Greenhouse Challenge Criteria handout to identify the Objectives, Tasks, Success Criteria, and Time Frame field to complete on the Action Plan. Emphasize to students the importance of having an initial plan to begin a project. A checklist and session timeline are included below to help design teams complete their Design Team Action Plans. Students need to prepare the following before Session Seventeen (presentations):
    a. Sketches (Session Ten)
    b. 3-D Tinkercad drawings to scale (Session Eleven)
    c. Approved Subcontractor List & Materials Budget (Session Twelve - Fourteen)
    d. Greenhouse prototype model (Session Thirteen - Fourteen)
    e. Results from temperature experiments (Session Fifteen)
    f. A Proposed Growing Plan for the greenhouse prototype (Session Fifteen and Sixteen)
    g. Ideas for improving the greenhouse prototype in the future (Session Fifteen and Sixteen)
    h. Design Teams will develop and give a 10-minute presentation to sell their classroom greenhouse prototype to the class. The presentation must include a design team Business Name and Logo and a name for the greenhouse prototype (Session Seventeen).

    Note: Students will not complete the 'Evaluate' or 'Recommendations' section of the Action Plan until Sessions Fifteen & Sixteen.

5. Once each team has completed its Design Team Action Plans, it should be presented and reviewed by the teacher. At this time, the teacher can provide critical feedback to the design group.

6. *Optional:* If the teacher wants to incorporate team member accountability, this is an opportune time to mention any educational supports the teacher may use (e.g. peer evaluations, etc.) to provide students with feedback at the end of the design team experience.

3.12.4 Wrap-Up - 5 minutes

Discuss with students any questions or concerns about the challenge to make sure students are on path to the intended objectives and outcomes. Prompt them with some questions and statements:

- What building materials are they planning to use to build their model?
- Add information about materials and cost to the design solution plans.
- Remember the dimensions of the greenhouse prototype floor must be 50 x 50 cm.
- Are you running into any challenges?
- Use your STEAM Research Notebooks to sketch, capture thoughts, and plan ideas

3.12.5 Deliverables for Session Twelve

At the end of the session, students should have completed the following:

- Final sketches of design team greenhouse prototype in STEAM Research Notebooks
- Design Team Action Plan (1 per team)

3.12.6 SESSION TWELVE RESOURCES

Design Team Action Plan (Figure 3.12.1)

Greenhouse Challenge Criteria Sheet (from Session Ten)

Approved Subcontractor List & Materials Budget (from Session Eleven)

Design Team Action Plan

Company Name: ____

Greenhouse Name: ___________________________________

Team Members: ____

____

Prepared by: ______________________ **Date:** ______________________

Objectives (List of Team Objectives, e.g. transfer sketch to Tinkercad, Create Materials Budget, Develop Presentation, etc.)	**Tasks** (What does your team need to do to achieve objectives and **WHO** will do the work, e.g. Billy and Jean will finish the hand-drawn sketch and draw a digital model in Tinkercad that is to scale.)	**Success Criteria** (How can your team identify its success, e.g. a 3-D model to scale that can be used to compile material list)	**Time Frame** (By what date does your team need to achieve the tasks, e.g. by the end of session 13)

Evaluate your greenhouse's overall performance:

Recommendations for future greenhouse build:

3.13 SESSION THIRTEEN - Greenhouse Prototype Build Day I - 40 minutes

This session is devoted to building the greenhouse prototypes. Using the design sketch each team created, teams will begin building their prototypes along with working on project documentation (e.g. materials budget, Tinkercad scaled drawing, etc.). Students should be encouraged and supported along the way to manage the project in a delegated fashion. Successful completion of the project timeline will depend on delegating tasks to teammates with multiple efforts happening simultaneously. Each team member's contribution and leadership is significant to the challenge solution.

3.13.1 Teacher Preparation, Session Thirteen

Teachers should assemble materials, duplicate handouts, and preview videos used in the session. Each school will have its own standards for safety. The teacher should provide safety guidance in compliance with local school policies.

Teacher Materials:

Classroom safety presentation (teacher prepared)

Engineering Design Process

Digital Resources:

Tinkercad: https://www.tinkercad.com/learn/

Internet access

Student Materials:

STEAM Research Notebook

Pen or Pencils (multiple colors)

Student greenhouse prototype materials (1 per design team):

Optional: To save time, pre-cut materials for students to use during build.

Structural Frame must be made of wood, metal, or plastic (pvc pipes)

Acrylic or Plexiglas or Plastic for wall coverings

Hot glue gun or glue sticks, expandable glue (e.g. Gorilla Glue), tape, and nails

Hammer, saws, stapler

Soil and plants

Thermometer

Tools to share (saws, hammers, etc.)

Handouts:

Greenhouse Challenge Criteria Sheet (from Session Ten)

Approved Subcontractor List & Materials Budget (from Session Eleven)

Design Team Action Plan (from Session Twelve)

Table 3.13 Explicit Knowledge Required for Session Thirteen

Core Area	Knowledge Required	Supports for Student Learning
Science	*Nature of scientific inquiry.* Students should understand that scientists ask questions and use observations and measurements through thoughtfully designed inquiries to collect data about their questions. Scientists keep records of the data they collect and their ideas in scientific notebooks.	Teachers will review the purpose of the notebook and its format with students and will provide examples of scientists and their work.
Mathematics	Students should be able to generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.	Students will draw comparisons between different types of growing systems that were designed to provide particular solutions with a limited set of available materials.
	Students should understand that the key to engineering is the design. Engineering uses science and technology to solve practical problems by designing solutions and manufacturing products and processes.	Teacher reviews the EDP with students.

Mathematics	Students should understand that a budget is a plan to help people make personal economic decisions for the present and future and to become more financially responsible. Students will consider the material costs for building a greenhouse as they select their prototype	The teacher will facilitate student conversations as they discuss potential challenges, rewards, and maintenance items associated with building the greenhouse with different materials.
	Data collection and analysis Students should be able to use appropriate methods (such as counting, measurement, experiment, etc.) to collect data according to simple questions, and record the data.	Students use the Design Team Action Plan handouts to guide their data collection about their peer's greenhouse designs.
	Students should be able to calculate the area and volume of circles, triangles, and polygons.	The teacher will provide support and answer student questions during sketching activities.
	Students should be able to use ratio reasoning to manipulate and convert measurement units as part of a model sketch.	
Science/ Language Arts	Students should understand that research is a necessary component of scientific inquiry and engineering design. Students should understand that research involves investigating how other people have solved similar problems or investigating products or devices designed with goals similar to their design goals. Students should understand how to take brief notes on their observations and sort evidence into categories.	Students share ideas about what makes a good greenhouse as an introduction to their research. The teacher can introduce the term *research* and communicate to students that research is important in product development in order to understand what is attractive to consumers and to avoid duplicating products that are already in production.

Social Studies/21st Century Skills	Students should understand that people often work in teams to solve problems. Students should understand that communicating clearly with team members is important for successful teamwork. Students should understand that listening to others' ideas and sharing their own ideas respectfully is important for successful teamwork.	Students continue to work in teams in this session and will continue teamwork throughout the unit, practicing and developing teamwork skills in each session. If students are new to working in teams, the teacher can prompt the class to develop a list of guidelines for good teamwork that includes such points as listening to others, being respectful, sharing ideas, being accountable for individual work, etc.
Arts	Students should be able to use basic materials (e.g. woodsticks, plastic, glue, nails, plexiglass, etc.) to construct and design prototype of sketch and CAD greenhouse images.	The teacher and other students will support each other as team to build and construct the greenhouse prototype.

3.13.2 Introduction - 10 minutes

Session Thirteen will provide students with the opportunity to **CREATE**, **TEST**, and **IMPROVE** their designs as student design teams begin building their greenhouse prototypes. The teacher should review the EDP with students. By now, students should be very clear about the criteria and objectives of the challenge. Today they will follow their Action Plan and sketches to build a greenhouse prototype (**CREATE**). They will **TEST** their plan by trying out different building materials to see what works and what does not work well. Finally, they will **IMPROVE** their plan and design by making adjustments and adaptations to the original idea to make the outcome better.

Students are likely to be very excited for the building sessions. It is important to enjoy that emotion, but also keep in mind that students will be using tools that pose potential dangers (e.g. hand saws, nails, hammers, etc.). The teacher should prepare and deliver a safety presentation to ensure proper care and procedures are taken into consideration while students build using different tools and materials.

3.13.3 Activity - Greenhouse Prototype Build Day I - 25 minutes

1. Students divide into their design team to revisit their Action Plan, and make any adjustments necessary before building.
2. Students should have their greenhouse prototype sketch completed with a 50 x 50 cm floor plan.
3. Before design teams build, they must get initial building permission by reviewing their design and Action Plan with the teacher.
4. Design Teams begin building greenhouse prototype.
5. Given the delegated tasks and roles assigned in the Action Plan, over the next few sessions (Session Thirteen - Sixteen) students should be:
    a. Building greenhouse prototype
    b. Tracking the materials used for building to create their greenhouse prototype materials budget
    c. Sketching changes to design as adjustments and improvements are made
    d. Drawing the FINAL greenhouse prototype 3-D model in Tinkercad
    e. Thinking about their greenhouse prototype growing plan
    f. Designing a team name and business logo, and greenhouse prototype name
    g. Organizing information that will go into their presentation
6. Every student should be very busy working on a project at this time.

3.13.4 STEAM Research Notebook Entry - 5 minutes

Have students reflect in their STEAM Research Notebooks on their first building day by answering the following questions:

- How well is your proposed design working?
- Did your prototype hold together with initial materials proposed?
- Does your floor plan span 50 x 50 centimeters?
- What modifications do you need to make to the design?

- Have you documented the design changes in your notebook?

3.13.5 Deliverables for Session Thirteen

At the end of the session, students should have completed the following:

- Finalized team sketch for greenhouse prototype
- Initial work on building greenhouse prototype
- Student entries in STEAM Research Notebooks

3.13.6 SESSION THIRTEEN RESOURCES

Greenhouse Challenge Criteria Sheet (from Session Ten)

Approved Subcontractor List & Materials Budget (from Session Eleven)

Design Team Action Plan (from Session Twelve)

3.14 SESSION FOURTEEN - Greenhouse Prototype Build Day II - 40 minutes

Session Fourteen is devoted to completing the build of the greenhouse prototype. Using the design sketch each team created, student groups will finalize building their prototype along with working on project documentation (e.g. materials budget, Tinkercad scaled drawing, etc.). Students should be encouraged and supported along the way to manage the project in a delegated fashion. Successful completion of the project timeline will depend on delegating tasks to teammates with multiple efforts happening simultaneously. Each team members contribution and leadership is significant to the challenge solution.

3.14.1 Teacher Preparation, Session Fourteen

Teachers should assemble materials, duplicate handouts, and preview videos used in the session.

Teacher Materials:

Classroom safety presentation (teacher prepared)

Digital Resources:

Tinkercad: https://www.tinkercad.com/learn/

Internet access

Student Materials:

STEAM Research Notebook

Pen or Pencils (multiple colors)

Student greenhouse prototype materials (1 per design team):

Optional: To save time, pre-cut materials for students to use during build.

Structural Frame must be made of wood, metal, or plastic (pvc pipes)

Acrylic or Plexiglas or Plastic for wall coverings

Hot glue gun or glue sticks, expandable glue (e.g. Gorilla Glue), tape, and nails

Hammer, saws, stapler

Soil and plants

Thermometer

Tools to share (saws, hammers, etc.)

Handouts:

Greenhouse Challenge Criteria Sheet (from Session Ten)

Approved Subcontractor List & Materials Budget (from Session Eleven)

Design Team Action Plan (from Session Twelve)

Greenhouse Prototype Crop Management Plan

Table 3.14 Explicit Knowledge Required for Session Fourteen

Core Area	Knowledge Required	Supports for Student Learning
Science **Mathematics**	Students should be able to generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.	Students will draw comparisons between different types of growing systems that were designed to provide particular solutions with a limited set of available materials.
	Students should understand that the key to engineering is the design. Engineering uses science and technology to solve practical problems by designing solutions and manufacturing products and processes.	Teacher reviews the EDP.
Mathematics	Students should understand that a budget is a plan to help people make personal economic decisions for the present and future and to become more financially responsible. Students will consider the material costs for building a greenhouse as they select their prototype	The teacher will facilitate student conversations as they discuss potential challenges, rewards, and maintenance items associated with building the greenhouse with different materials.
	Data collection and analysis Students should be able to use appropriate methods (such as counting, measurement, experiment, etc.) to collect data according to simple questions, and record the data.	Students use the Design Team Action Plan handouts to guide their data collection about their peer's greenhouse designs.

	Students should be able to calculate the area and volume of circles, triangles, and polygons. Students should be able to use ratio reasoning to manipulate and convert measurement units as part of a model sketch.	The teacher will provide support and answer student questions during sketching activities.
Language Arts	Students should be able to write narrative text about their experiences using effective technique, descriptive details, and clear event sequences. Students should understand the value of reflection and the habit of summing up their learning.	A writing rubric is included in the STEAM Research Notebook for students to use to self-assess their writing. The teacher will provide models of explanatory writing and science notebooks using books illustrating science notebooks such as the one recommended in Session 1.
Social Studies/21st Century Skills	Students should understand that people often work in teams to solve problems. Students should understand that communicating clearly with team members is important for successful teamwork. Students should understand that listening to others' ideas and sharing their own ideas respectfully is important for successful teamwork.	Students continue to work in teams in this session and will continue teamwork throughout the unit, practicing and developing teamwork skills in each session. If students are new to working in teams, the teacher can prompt the class to develop a list of guidelines for good teamwork that includes such points as listening to others, being respectful, sharing ideas, being accountable for individual work, etc.
Arts	Students should be able to use basic materials (e.g. woodsticks, plastic, glue, nails, plexiglass, etc.) to construct and design prototype of sketch and CAD greenhouse images.	The teacher and other students will support each other as team to build and construct the greenhouse prototype.

3.14.2 Introduction - 5 minutes

Session Fourteen will continue to provide students with the opportunity to work through the **CREATE**, **TEST**, and **IMPROVE** stages of the EDP as student design teams finish building their greenhouse prototypes. The teacher should remind students to be safe as they continue to **CREATE**, **TEST**, and **IMPROVE**, and that major milestones should be completed by the end of today. Design teams should focus on building their prototypes today and completing the steps of their Action Plans.

3.14.3 Activity - Greenhouse Prototype Build Day II - 30 minutes

1. Students divide into their design teams to revisit their Action Plans, and make any adjustments necessary before building.
2. Design Teams should have finalized the materials they are using for the construction of their greenhouse prototypes. Today is the last day of the build.
3. Given the delegated tasks and roles assigned in the Action Plan, multiple activities should be nearing completion by the end of today's session:
    a. Finalized sketch of greenhouse prototype model (Completed by Session Fourteen)
    b. 3-D Tinkercad drawing of greenhouse prototype model to scale (Completed by Session Fourteen)
    c. Greenhouse prototype model (Completed by Session Fourteen)
    d. Materials budget (Completed by Session Fourteen)
4. After design teams have finished their greenhouse prototype construction, have each group tape a thermometer at the same height from the floor level in a corner of the greenhouse. This will be used during the next session to test the greenhouse's ability to transfer heat.
5. Every student should be very busy working on a project at this time.

3.14.4 Wrap-Up - 5 minutes

Final sketches and Tinkercad drawings should be included in the students' STEAM Research Notebooks. design teams should wrap up this session by looking ahead at the last few session tasks for the Design challenge.

Give students the Greenhouse Management Plan Handout. Ask students to begin thinking about:

- What crops will be produced?
- During which months will those crops be grown?

Students will continue to work on completing the Greenhouse Management Plan during the next session.

3.14.5 Deliverables for Session Fourteen

At the end of the session, students should have completed the following:

- Final sketches in STEAM Research Notebooks
- Final drawings of design team greenhouse prototype in Tinkercad (1 per team)
- Greenhouse prototype model (1 per team)
- Materials Budget for the greenhouse prototype (1 per team)

3.14.6 SESSION FOURTEEN RESOURCES

Greenhouse Prototype Management Plan

Greenhouse prototype Management Plan Handout (p. 1)

Develop a management plan for plant production

In the space below (or in your STEAM Research Notebook), imagine and sketch the interior of the greenhouse prototype with plants growing inside. Include in your sketch the growing spaces (e.g. ground, benches, stages, vertical hangers, etc.) that will support plant growth. Please include what kind of watering system you are going to use (e.g. hand watering, drip irrigation, etc.), and how often plants will need watering.
*This handout will help you plan your strategy for what crops can be grown inside the greenhouse prototype (who, what, how, when, and where).

Provide an interior greenhouse sketch that shows your vision for the inside of your greenhouse and and the placement of plants.

Greenhouse Crop Management Plan Handout (p. 2)

1. What crops will be produced?

2. During which months will those crops be grown? Describe approximately how long it will take, and how the crop will develop, from planting to harvest.

3. Where will those crops be located inside of the greenhouse (e.g. vertical growing, on the ground, in a shelving system, etc.)?

4. Describe the greenhouse work that will be done weekly. This will include (at a minimum) seed propagation, planting, watering, weeding, and harvesting.

3.15 SESSION FIFTEEN - Greenhouse Temperature Experiments and Growing Plan - 40 minutes

In Session Fourteen, student teams completed the building of their greenhouse prototypes, and started thinking about the Greenhouse Crop Management Plan. Essential to success of the Classroom Greenhouse Challenge is putting together a growing plan that provides a strategy for the types of crops will be grown and how they will be cared for. During Session Fifteen, students will simultaneously work as design teams on developing their Crop Management Plans and conduct heat transfer experiments on their greenhouse prototypes to test their ability to absorb and maintain radiant energy.

3.15.1 Teacher Preparation, Session Fifteen

Teachers should assemble materials, duplicate handouts, and preview videos used in the session.

Teacher Materials:

Optional: Presentation on how greenhouse heating works (prepared by teacher in Session Ten) for review

Digital Resources:

Digital Presentation Software (e.g. PowerPoint, Prezi, Slides, etc.)

Internet access

Student Materials:

STEAM Research Notebook

Pen or Pencils (multiple colors)

Other Materials (1 per design team):

Greenhouse prototype

Soil

Tools to scoop the soil

2 thermometers (1 taped inside greenhouse; 1 to take temperature of air outside greenhouse)

Incandescent lamps (if greenhouses cannot be tested outdoors in the sun)

Handouts:

Greenhouse Challenge Criteria Sheet (from Session Ten)

Approved Subcontractor List & Materials Budget (from Session Eleven)

Design Team Action Plan (from Session Twelve)

Greenhouse Management Plan Handout (Session Fourteen)

Greenhouse Temperature Test Session

Greenhouse Temperature Test Session Graphing Example and Rubric

Table 3.15 Explicit Knowledge Required for Session Fifteen

Core Area	Knowledge Required	Supports for Student Learning
Science	Students should understand that energy released from food was once energy from the sun that was captured by plants in the chemical process that forms plant matter(from air and water).	Students working with their design teams will conduct temperature experiments to observe and measure their greenhouse prototype's ability to transfer heat.
	Students should understand that the key to engineering is the design. Engineering uses science and technology to solve practical problems by designing solutions and manufacturing products and processes.	Teacher reviews the EDP.
Mathematics	Students should be able to write and interpret numerical expressions.	The teacher will provide support to student teams as they take measurements in the Temperature Experiment.
	Students should be able to take brief notes on experiments and sort evidence into provided categories. Students will gather data and will discuss data with their groups and determine how changes can be accounted for.	Teachers will provide support during the sessions to make sure student teams are recording and gathering feedback from experiments and classmates.

	Students should be able to record measurements on a coordinate system according to the data of the proportional relationship given and to estimate the value of the other quantity based on the value of one of the amounts	The teacher will provide support and answer student questions during sketching activities.
	Students should be able to calculate the volume of a 3D rectangular prism based off the provided equation.	
	Students should be able to use ratio reasoning to manipulate and convert measurement units as part of a model sketch.	
Language Arts	Students should be able to use communication skills including letters, words, and sentences to communicate their ideas.	Teachers will support students to articulate their ideas.

3.15.2 Introduction - 5 minutes

At the beginning of Session Fifteen, the teacher should take a moment with the students to recognize their accomplishment in finishing the building component of their greenhouse prototypes. Review the Greenhouse Challenge Criteria Sheet along with the Design Team Action Plan. Ask students if they have completed all the tasks needed by the timeline. Tell students how many more 'working' days they have until their presentation and ask them what work must be done between now and then. At this point, students should have three major tasks to complete between now and the end of Session Sixteen:

1. A Proposed Growing Plan for the greenhouse prototype
2. Results from their Temperature Experiments
3. A digital presentation that 'pitches' their greenhouse prototype as the Classroom greenhouse

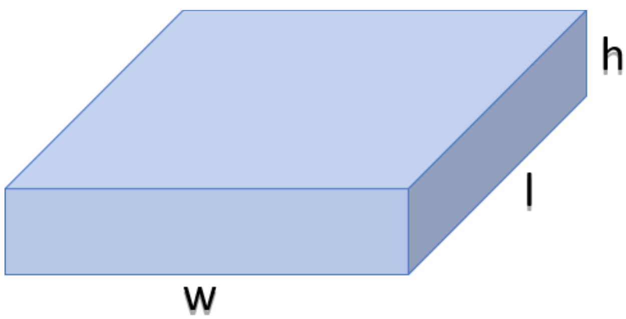
Remind students to keep delegating tasks to ensure all the work is completed.

Today students should focus on finishing their Crop Management Plans and conduct a temperature experiment to test their greenhouse prototypes. To transition to the temperature experiments, review with the students where they are in the engineering design process. Students have now completed the building of their greenhouse prototype, now it is time to **TEST** it. As they learned in Session Ten how a greenhouse transfers heat, today they test their model to see how well it transfers heat. Every model should have a thermometer taped to an inside corner of the greenhouse about 10 cm above the ground level.

3.15.3 Activity - Greenhouse Temperature Experiments and Growing Plan - 30 minutes

1. Students divide into their design teams to revisit their Action Plan, and make any adjustments necessary before moving on to next steps.
2. Introduce the temperature experiments: Provide each team with the Greenhouse Temperature Test Session handout. Also include the Graphing Example and Rubric.

Instruct each team to fill the ground floor of their greenhouse prototype with 8 cm depth of soil. Based on this depth, students should calculate the volume of soil used in this experiment based on volumetric equation for a rectangular prism (Figure 3.15.1):



$$V = l \, x \, w \, x \, h$$

3. Students should ensure the thermometer is not touching anything other than the greenhouse wall and tape. Further, instruct students to ensure they have sealed their greenhouse prototypes to the best of their abilities. Students can use tape as a temporary seal if needed.
4. If the day is sunny, take the class outside to test their greenhouses. If it is not sunny, set up incandescent lamps to provide a source of radiation. Students should follow the procedures on the

Greenhouse Temperature Test Session handout. As a control, students should record the ambient outdoor temperatures (outside the greenhouse) at each time interval.

5. Once testing is complete bring the class back inside to complete the graphing and analysis portions of their handouts.
6. NOTE: Students will have some time as they wait between temperature readings. Students should complete their Crop Management Plans during this time.

3.15.4 Wrap-Up - 5 minutes

The teacher should allow students time to complete the graphing and analysis activities and document results in their STEAM Research Notebooks. If there is enough time, have students compare results with one another and discuss the overall results as a class. Conclude with classroom discussion on the focused around the questions provided in the handout (Section: Graph Analysis, p. 3).

3.15.5 Deliverables for Session Fifteen

At the end of the session, students should have completed the following:

Greenhouse Temperature Test Session

Crop Management Plan

3.15.6 SESSION FIFTEEN RESOURCES

Greenhouse Temperature Test Session Handout

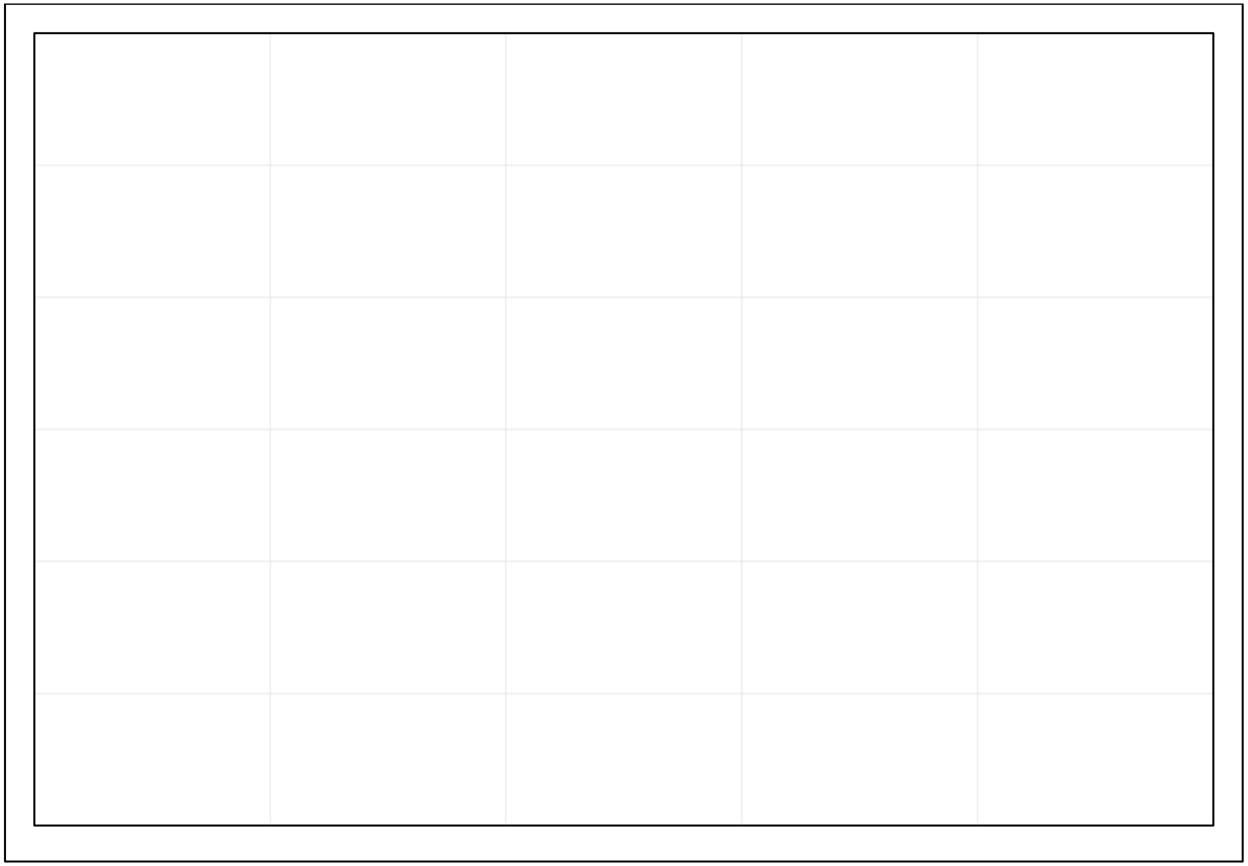
Greenhouse Temperature Test Session Handout (p. 1)

Determine the ambient (initial) temperature of the outdoor air. Place your greenhouse under direct sunlight with the thermometer inside. At each specified time interval, take a temperature reading inside the greenhouse. Also keep a record of the ambient outdoor temperature at the same time intervals.

Elapsed Time (minutes)	Inside greenhouse Temperature (°C)	Outside greenhouse Temperature (°C)
0 minutes (ambient outdoor temperature)		
5 minutes		
10 minutes		
15 minutes		
20 minutes		

Greenhouse Temperature Test Session Handout (p. 2)
Figure 3.15.2a: Graph the Results

On the axis below, plot the temperature readings inside and outside your model greenhouse as a function of time. Make the two lines different colors and include a legend to explain what the two colors represent. Make sure to include a title and appropriate labels.



Greenhouse Temperature Test Session Handout (p. 3)
Graph Analysis

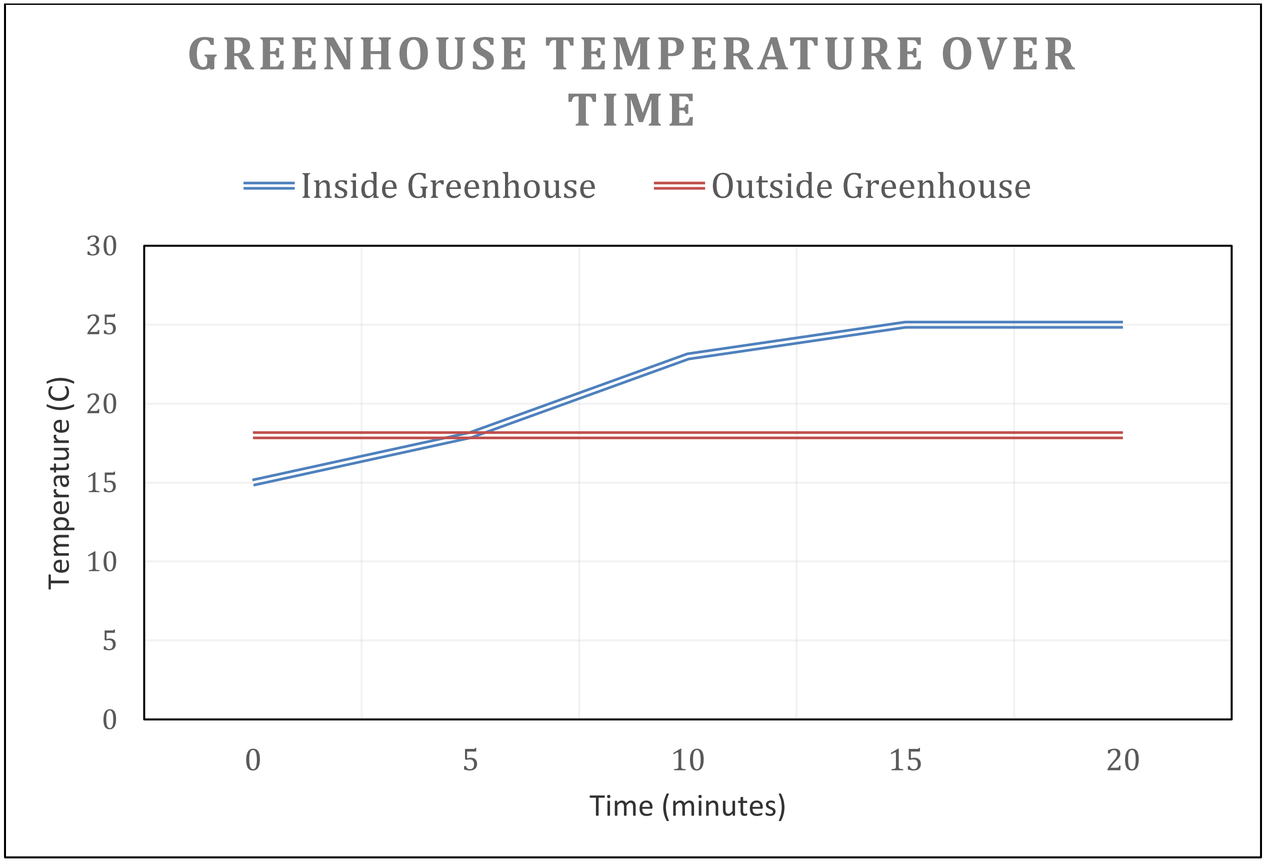
A. Looking at your graph, how does the temperature condition in your greenhouse compare to the ambient temperature of the air?

B. Explain the general shape of the lines on your graph and what they mean in terms of the performance of the greenhouse. What do the two different lines indicate?

C. Imagine you want to use the greenhouse year-round. On a cold and cloudy winter day, the greenhouse must be able to maintain a warm enough temperature to keep plants from dying. Since no sun is shining, radiation heat gain is virtually nothing. What are some ways to make up for heat loss from the greenhouse?

D. What is one way to prevent some of the heat loss during these conditions?

Figure 3.15.3: Temperature Graphing Example and Rubric



Five Points Total – 1 point for each of the following:

1. x-axis labels with units
2. y-axis labels with units
3. title that describes the graph
4. legend
5. overall neatness and readability

3.16 SESSION SIXTEEN - Greenhouse Presentation Development - 40 minutes

In Session Sixteen, students will pull together all their engineering design process activities for the development of their greenhouse prototype into a 10-minute digital presentation (e.g. PowerPoint, Prezi, Slides, etc.) that will be shared with the class. The teacher will provide a short presentation demonstration to emphasize important aspects of effective communication for students to consider. Students will be given a Greenhouse Presentation Rubric to provide them guidelines as they develop their final presentation. The majority of this session will be for students to develop their presentation.

3.16.1 Teacher Preparation, Session Sixteen

Teachers should assemble materials, duplicate handouts, and preview videos used in the session. The teacher should review the *Digital Resources* provided to develop a presentation to share with students on the components of effective presentations. The teacher should demonstrate the values and qualities that are important to the school and community during their example presentation.

Teacher Materials:

Short Presentation demonstration to model the elements of an effective presentation (prepared by teacher – see *Digital Resources* for ideas)

Digital Resources:

Internet access

Digital Presentation Software of Choice (e.g. PowerPoint, Prezi, Slides, etc.)

Resource with Creative Presentation Tool Ideas: https://www.spart5.net/cms/lib/SC01000802/Centricity/Domain/804/NotAnotherPowerpointHandout.pdf

Resource for Presentation Strategies for Engineering Students by Carnegie Mellon University's Global Communication Center: https://www.cmu.edu/gcc/handouts/handouts-new/presentation-strategies.pdf

Resource for Making and Giving Effective Group Presentations:

https://www.monash.edu/__data/assets/pdf_file/0007/567133/group-presentations.pdf

Student Materials:

STEAM Research Notebook

Pen or Pencils (multiple colors)

Other Materials:

Greenhouse prototype

Handouts:

Greenhouse Challenge Criteria Sheet (from Session Ten)

Approved Subcontractor List & Materials Budget (from Session Eleven)

Design Team Action Plan (from Session Twelve)

Greenhouse Management Plan Handout (Session Fourteen)

Greenhouse Temperature Test Session Handout (Session Fifteen)

Greenhouse Presentation Rubric Handout

Table 3.16 Explicit Knowledge Required for Session Sixteen

Core Area	Knowledge Required	Supports for Student Learning
Art	Students should be able to produce artistic products that demonstrate consideration of elements of line, color, shape, texture, impasto, and orientation (landscape and portrait). Students will apply knowledge of art as they construct their greenhouse Presentation.	The teacher will provide feedback on student team choice of artistic representations.
Technology	Students should be able to use technology as a tool to research, organize, evaluate, and communicate information. Student teams will use computers to organize and communicate their presentations	The teacher will assist student teams in using presentation software to complete the task in this session.
Language Arts	Students should be able to use communication skills including	Teachers will support students to articulate their ideas.

	letters, words, and sentences to communicate their ideas.	
	Students should be able to introduce a topic, state an opinion or reflect on their reactions to text, and create an organizational structure that provides appropriate detail.	A writing rubric is included in the STEAM Research Notebook for students to use to self-assess their writing. The teacher can provide examples of reflective writing modeling complete sentences and inclusion of detail.
Social Studies/21st Century Skills	Students should understand that people often work in teams to solve problems. Students should understand that communicating clearly with team members is important for successful teamwork. Students should understand that listening to others' ideas and sharing their own ideas respectfully is important for successful teamwork.	If students are new to working in teams, the teacher can prompt the class to develop a list of guidelines for good teamwork that includes such points as listening to others, being respectful, sharing ideas, being accountable for individual work, etc.

3.16.2 Introduction - 5 minutes

The teacher should open up today's session with a review of the EDP and emphasize the **SHARE** phase. Leading up to this point, students have **ASKED**, **IMAGINED**, **PLANNED**, **CREATED**, **TESTED**, **IMPROVED**, and now it is time to **SHARE**. The teacher should emphasize that the EDP need never stop, that there is always room to ask more questions, create new models, and improve. However, given the time constraints on this Classroom Greenhouse Challenge, teams will share their prototypes and related work as a concluding activity. The teacher should briefly review the presentation goals and objectives emphasizing the goal for each design team to show their design to others and get feedback. The teacher should share that each individual student as well as the teacher will be providing feedback on each design team's model and presentation. Each student will also be voting for design team awards, which include:

Most Innovative Design

Most Economical Design

Most Creative Design

Most Fun Presentation

Overall BEST Greenhouse Prototype

Review elements of effective presentations with students (e.g., identify your presentations' purpose; introduce the presenters; use visual aids; organize your presentation so it has a beginning, middle and end; make eye contact with audience; and speak in a clear and audible voice). Show students the sample presentation you prepared.

3.16.3 Activity - Greenhouse Presentation Development - 30 minutes

1. Students divide into their design teams to revisit their Action Plans, and make any adjustments necessary before moving on to next steps.
2. Hand out Greenhouse Presentation Rubric.
3. Students and teacher should read through the Rubric, noting that ALL students on the design team must speak and they must stay within the 5-minute time frame.
4. Remind design teams that they should delegate and assign tasks (e.g. dividing out tasks and assigning them to students, such as STUDENT A works on putting together SLIDES A & B). Students can revisit their Action Plan document and begin to organize their presentations:
    a. Organize the structure of the presentation by creating sections (e.g. Introduction, Middle Sections, Conclusion, Demonstration, etc.)
    b. Decide where visuals are needed and prepare those visuals. Make sure they are effective
        i. Keep the message simple.
        ii. Avoid long lists and sentences, 'A picture is worth a thousand words.'
        iii. Give every slide a title.
        iv. Plan on each slide lasting approximately 1 minute. For a ten-minute presentation, have at least 10 slides.

c. Prepare the talk. Make the language of your presentation formal, and avoid informal language and slang.
d. Prepare notes for talking points.
e. Rehearse the presentation with the group. Check timing, structure, delivery, and make adjustments when necessary to prepare for the final version. Rehearse again.

5. Students should be strongly encouraged to rehearse and rehearse their talking points with each other; Session Sixteen is the only session committed exclusively to Greenhouse Presentation Development.

3.16.4 Wrap-Up - 5 minutes

Students should spend the last 5-minutes of class practicing their presentation and asking any individualized questions they might have as a group. Session Seventeen is Presentation Day!

3.16.5 Deliverables for Session Sixteen

At the end of the session, student teams should have completed the following:

- Design Team Greenhouse Presentation preparation

3.16.6 SESSION SIXTEEN RESOURCES

Greenhouse Presentation Rubric

Greenhouse Presentation Rubric

Criteria	Exemplary (4 points) Best Work	Mastery (3 points) Good Work	Approaching (2 points) Working On It	Incomplete (1 point) Unsatisfactory	Student Evaluation	Teacher Evaluation
Communication Skills						
Presenters looked at audience						
Presenters spoke clearly (loud, slow, and without hesitation)						
Presenters spoke enthusiastically						
Each person on design team spoke						
Presentation Quality						
Team presented a unique business name and logo						
Team presented a greenhouse prototype name						
Presentation stayed within time limit						
Slides had interesting visuals and were well crafted						
Content and Organization						
Team talked about the challenge problem the product solves and what makes it unique						
Team talked about their design process including design criteria elements:						
• Interior & Exterior greenhouse Sketches						
• 3-D Tinkercad Drawings were to scale						
• Built greenhouse prototype Model						
• Materials Budget and estimated cost						
• Results from temperature experiments						
• Developed crop management plan						
• Ideas for improving the greenhouse						

3.17 SESSION SEVENTEEN - Greenhouse Challenge Presentation Day - 40 minutes

Session Seventeen is the Greenhouse Challenge Presentation Day! Today, student teams 'sell' their greenhouse prototype to the classroom by demonstrating their engineering design process and their greenhouse prototype. Students will provide peer feedback by completing the Greenhouse Presentation Rubric for each design team and voting on student awards. The teacher will also provide design teams with feedback using the same rubric.

3.17.1 Teacher Preparation, Session 17

Teachers should provide a space for student presentations and secure the necessary technology to present teams' digital presentations. Create a schedule for teams to make their presentations. Pre-load teams' presentation into the audio/visual equipment that will be used for the presentations.

Teacher Materials:

Schedule of presentations and design team introductions (Teacher Prepared)

Digital Resources:

Internet access

Projector, Audio/Video Needs for Presentation Display

Digital Presentation Software (e.g. PowerPoint, Prezi, Slides, etc.)

Student Materials:

STEAM Research Notebook

Pen or Pencils (multiple colors)

Other Materials:

Greenhouse prototypes

Greenhouse presentations

Handouts:

Greenhouse Presentation Rubric Handout (from Session Sixteen) - each student should receive one rubric handout per design team presentation

Greenhouse Design Team Award Voting Ballot

Table 3.17 Explicit Knowledge Required for Session Seventeen

Core Area	Knowledge Required	Supports for Student Learning
Art	Students should be able to produce artistic products that demonstrate consideration of elements of line, color, shape, texture, impasto, and orientation (landscape and portrait). Students will apply knowledge of art as they present their greenhouse presentations.	The teacher and students will provide feedback on student team choices of artistic representations.
Technology	Students should be able to use technology as a tool to communicate information.	The teacher will assist student teams in using presentation software to complete the task in this session.
Language Arts	Students should use communication skills including letters, words, and sentences to communicate their ideas.	Teachers will support students to articulate their ideas.
Social Studies/21st Century Skills	Students should understand that people often work in teams to solve problems. Students should understand that communicating clearly with team members is important for successful teamwork. Students should understand that listening to others' ideas and sharing their own ideas respectfully is important for successful teamwork.	The teacher can refer to guidelines for good teamwork that includes such points as listening to others, being respectful, sharing ideas, being accountable for individual work, etc.

3.17.2 Introduction - 5 minutes

Begin Presentation Day with a smile and encouragement, and tell students that these are part of being good audience members. The teacher will share the presentation day schedule. Each student will be scoring other design teams and providing feedback using a rubric. Each student individual may have a slightly different perspective to offer; however, the rubric is a guide to try and keep the evaluation process objective. Talk with the students about the word 'objectivity' and how in science, scientists try to remain objective - that is making observations that are free of personal feelings and paying close attention to facts as they are presented. However, feelings are important to and students will have an opportunity to vote on design team awards that are based more on feeling and less on fact. Remind students that standing up and speaking in front of their class requires courage, and that as an audience we want to be respectful and good listeners. Discuss with the students some characteristics of good listeners:

- They pay attention to the person who is speaking.
- They keep eye contact.
- They show interest by nodding or by smiling at appropriate times.
- If they have a question, they write it down and wait to ask the question until the appropriate time.
- They applaud the presenters/speakers for their courage and effort.

3.17.3 Activity - Greenhouse Challenge Presentation - 30 minutes

1. Teacher should have the presentations pre-loaded into audio/visual equipment that will be used for the presentation.
2. Hand-out multiple Greenhouse Presentation Rubrics to each student (1 for each design team).
    a. If students have any questions about how to complete the rubric, this is now the time to ask.
3. Presentations
    a. The teacher, as the Master of Ceremonies, should introduce each design team by their company.
    b. Each design team is given 5 minutes to present and pitch their greenhouse prototype concept.
4. After each presentation, time should be given to students to complete the rubric for the given presentation.

5. ‘That’s a Wrap!’ Congratulate students on their efforts and courage for presenting today, as well as their accomplishments in working together as a team to meet all the objectives and work under a challenging set of criteria and constraints.

3.17.4 Wrap-Up and STEAM Research Notebook Entry– 5 minutes

Students should have completed a rubric for each presentation; if extra time is needed, make sure they are given the time during wrap-up. Pass out the student voting ballots. Explain the voting process and the define (as the teacher sees fit) the different categories they are voting on. Students will then vote, and teacher will collect votes. Votes will be tallied by the teacher and presented during Session Eighteen.

Finally, allow students an opportunity to provide feedback in their STEAM Research Notebooks. Prompt students with the questions: What did they enjoy the most about Presentation Day? What did they enjoy the least? What is one skill they thought they were pretty good at during the presentation? What is one skill they would like to work on before their next presentation?

3.17.5 Deliverables for Session Seventeen

At the end of this session, students should have completed the following:

- Design Team Greenhouse Presentation
- Presentation Rubrics for each design team
- Voted on various design award categories
- Entry in STEAM Research Notebook

3.17.6 SESSION SEVENTEEN RESOURCES

Greenhouse Presentation Rubric

Greenhouse Design Team Award Voting Ballot

Greenhouse Presentation Rubric

Criteria	Exemplary (4 points) Best Work	Mastery (3 points) Good Work	Approaching (2 points) Working On It	Incomplete (1 point) Unsatisfactory	Student Evaluation	Teacher Evaluation
Communication Skills						
Presenters looked at audience						
Presenters spoke clearly (loud, slow, and without hesitation)						
Presenters spoke enthusiastically						
Each person on design team spoke						
Presentation Quality						
Team presented a unique business name and logo						
Team presented a greenhouse prototype name						
Presentation stayed within time limit						
Slides had interesting visuals and were well crafted						
Content and Organization						
Team talked about the challenge problem the product solves and what makes it unique						
Team talked about their design process including design criteria elements:						
• Interior & Exterior greenhouse Sketches						
• 3-D Tinkercad Drawings were to scale						
• Built greenhouse prototype Model						
• Materials Budget and estimated cost						
• Results from temperature experiments						
• Developed crop management plan						
• Ideas for improving the greenhouse						

Greenhouse Design Awards Ballot

Student vote for:

GREENHOUSE DESIGN AWARDS	FIRST PLACE TEAM	SECOND PLACE TEAM
Most innovative design		
Most economical design		
Most creative design		
Most fun presentation		
Overall BEST greenhouse design		

Print your name: ____

Student signature & date: ____

3.18 SESSION EIGHTEEN - Synthesis of Unit Sessions and Challenge - 40 minutes

Students and teacher will review feedback from the student presentations. Certificates will be given to the top designs in each category. The class will utilize the session to discuss plans to integrate and maintain the greenhouse prototypes in the classroom.

3.18.1 Teacher Preparation, Session Eighteen

Teachers should assemble materials used in the session. Since this is the last session and awards will be presented, this is a great opportunity to acknowledge students' hardwork and determination with a special ceremony. Student Award Certificates should be prepared ahead of time.

Teacher Materials:

Award Certificate Template (Teacher prepared for each award category and winners)

Digital Resources:

Internet access

Student Materials:

STEAM Research Notebook

Pen or Pencils (multiple colors)

Table 3.18 Explicit Knowledge Required for Session Eighteen

Core Area	Knowledge Required	Supports for Student Learning
Science	Students should understand that the key to engineering is the design and in this session they will use consumer feedback to redesign their product as needed.	Teacher continues to facilitate the design process and provides clarification as needed.
	Students should be able to generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.	Students will draw comparisons between different types of growing systems that were designed to provide particular solutions with a limited set of available materials.
Mathematics	Students should understand that a consumer is a person whose	The teacher will discuss with student teams strategies for

	wants are satisfied by using goods and services. A producer makes goods and/or provides services. Students will use their understanding of consumers and producers to determine the best output of product given a set of modifiable variables.	maximizing production and profits given different variable constraints to consider.
	Students should be able to calculate the volume of a 3D rectangular prism and right cylinder based off the provided equation.	The teacher will provide support and answer student questions during sketching activities.
	Students should be able to write and interpret numerical expressions.	
	Students should be able to use ratio reasoning to manipulate and convert measurement units as part of a model sketch.	
Language Arts	Students should be able to use data from their consumer prototype testing (Greenhouse Presentations) and discuss data with their groups.	Teachers will provide support during the session to make sure student teams are using feedback from consumers to redesign their prototype as necessary.

3.18.2 Introduction - 10 minutes

The teacher should start out by congratulating each of the design teams on the work they've accomplished during this unit. The teacher should discuss any feedback and follow up from the presentation session. This should reinforce best practices for presentation methods and communication. Near the end of this discussion the teacher should hand out awards based on the student rankings during the previous session. These categories included:

Most Innovative Design

Most Economical Design

Most Creative Design

Most Fun Presentation

Overall BEST greenhouse prototype

3.18.3 Activity -20 minutes

The teacher should explain that the student greenhouse prototypes will be maintained in the classroom. Each greenhouse prototype will provide 50 x 50 cm space for growing different types of plants but also provide opportunities for future experiments. Also, thanks to the collective effort and creativity from the class, the variety in designs may allow for different strengths for certain kinds of plants. However, in order to get the benefit of scaling the work done in each of the design teams, it is necessary to streamline and integrate the management and maintenance of these greenhouse prototypes. In this activity, students will work on developing an overall Crop Management Plan for the entire set of greenhouse prototypes as well as complete a conceptual sketch for a semi-automated watering system.

The class should split up into two groups. One group will work on a conceptual sketch for a semi-automated watering system that can connect to each of the greenhouse prototypes. Remind students of their research in Session Eight and the Hydroponics in a Bottle activity regarding on how siphons and self-watering planters work. These concepts will be useful in coming up with a concept that will be successful. If each greenhouse prototype needs 2.5 cm of water per week, using the equation for calculating the volume of a rectangular prism how much water is needed for each irrigation event? If we wanted to store enough water to meet our irrigation needs for an entire month (4-weeks), how much water would we need to store? Using the volumetric equation for a right cylinder ($V = \pi r^2 h$), which approximates a water collection cistern with radius “r” and heigh “h”, what would be the radius of a 8-ft tall cistern that stores a month’s supply of irrigation water?

The second group should develop a growing plan (similar to the ones develop in Session Nine) that is suited to the capabilities and strengths of each of the greenhouse prototype designs. The growing plan should consider aspects such as overall growing season length provided by the greenhouse prototype designs and depth of the growing medium where roots can grow. An ideal growing plan will include a variety of crops that can be rotated and grown throughout the growing season provided by the greenhouse prototypes. Students should write down which crops will be grown in which greenhouse prototype and specify a crop rotation if one is used.

At the end of this activity, each group should spend 3 minutes presenting their results

3.18.4 Wrap-Up and STEAM Research Notebook Entry- 10 minutes

The final wrap-up for the unit should allow for students to make comments about which aspects of the sessions and activities they enjoyed the most in this unit. Have students respond to the following in their STEAM Research Notebooks: Which sessions and activities did they find most challenging? What type of activities or topics would they include more of next time?

3.18.5 Deliverables for Session Eighteen

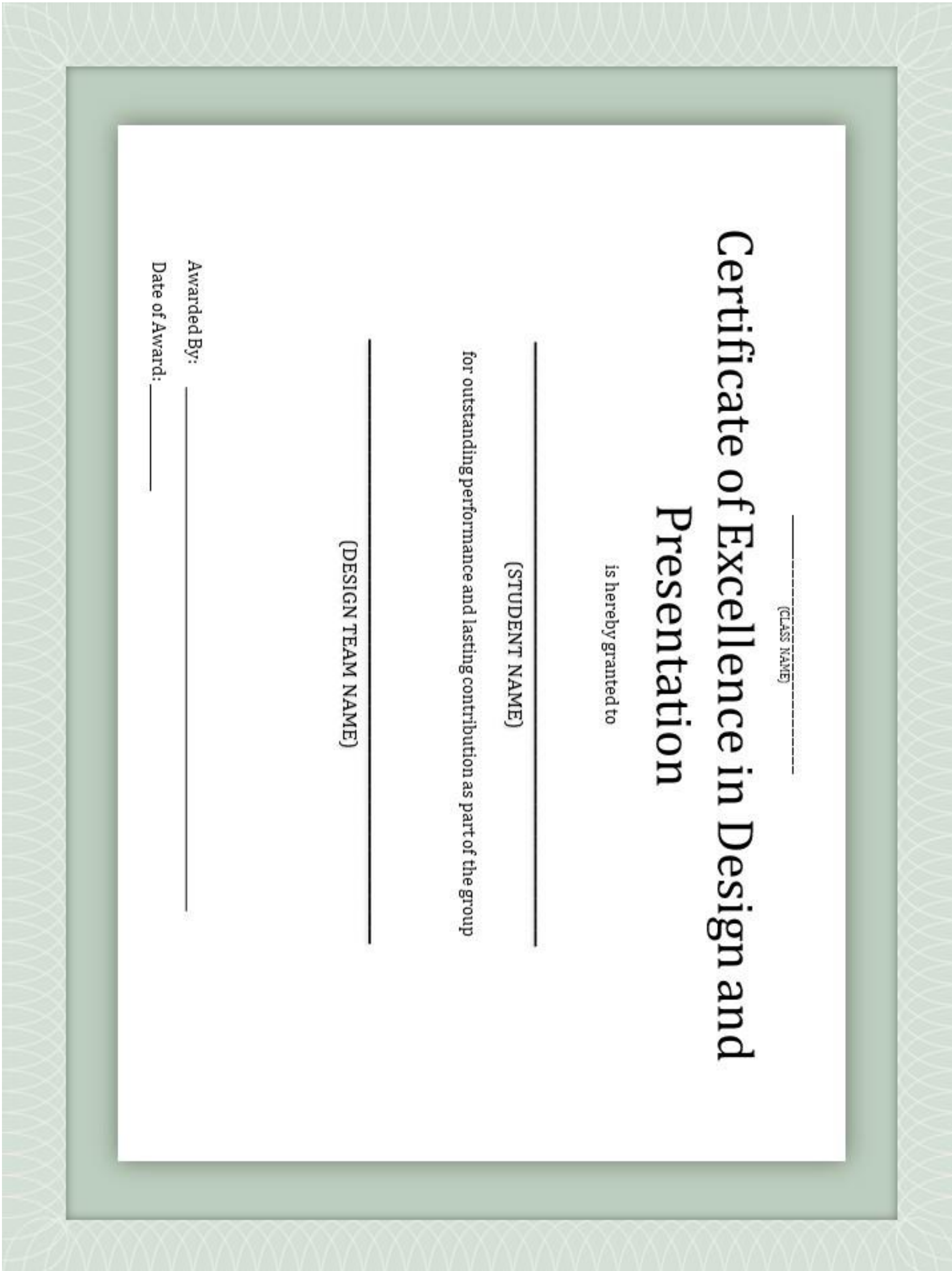
At the end of this session the students will have completed the following:

- Conceptual sketch of a semi-automated watering system that can connect each of the greenhouse prototypes
- Growing Plan for the suite of greenhouse prototypes
- Final comments in their STEAM Research Notebooks

3.18.6 Resources

Award Certificate Template

Figure 3.18.1: Award Certificate Template



4.0 Appendix A – Supplemental Sessions

Sustainable Systems and Designing a Classroom Greenhouse – Grade 6

4.1 Supplemental Session One – Nitrogen Cycle – 40 minutes

In this Supplemental Session, students will explore the nitrogen cycle further to better understand concepts and dynamics in how nitrogen moves through controlled environment agriculture systems. Students will work individually to diagram their own nitrogen cycles for a greenhouse system.

4.1.1 Teacher Preparation, Supplemental Session One

The teacher should preview the Nitrogen Cycle handout and review the article, "**The Nitrogen Cycle: Processes, Players, and Human Impact" (Bernhard 2010). Handouts should be printed off for each student prior to the start of the session.**

Student Materials:

STEAM Research Notebook

Pen or Pencils (multiple colors)

Other Materials:

Bernhard, A. (2010) The Nitrogen Cycle: Processes, Players, and Human Impact. *Nature Education*

***Knowledge* 3(10):25**

Fertilizer labels (≥5); should be from different types of fertilizer (e.g. granular, liquid)

Handouts:

Nitrogen Cycle

Table 4.1 Explicit Knowledge Required for Supplemental Session

Core Area	Knowledge Required	Supports for Student Learning
Science	Students should understand that plants require nutrients to live and grow.	Students will develop their own nitrogen cycles based on the provided handout and video.
	Students should understand that plants acquire their material for growth chiefly from air and water, and that matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment.	The teacher will provide background knowledge and examples about controlling factors in plant growth, biogeochemical cycling, and CEA systems
Language Arts	Students should be able to explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical, scientific, or technical text based on specific information in the text.	Teacher will model and provide examples of applying information from images, illustrations, experiments, and text to draw connections between concepts.

4.1.2 Introduction – 15 minutes

The teacher should start this session by asking questions such as: What is the most important nutrient that plants need to grow? Where do plants get these nutrients? How do nutrients move through air, soil, and water? This introduction should highlight that nitrogen is one of most important nutrients to plant growth and is needed by all living organisms to make things like the proteins and DNA that our bodies use to function.

Following a brief discussion, the teacher should distribute the Nitrogen Cycle handout to each student in the class. The teacher should spend approximately 10-12 minutes highlighting the primary forms and processes within the Nitrogen Cycle handout. Key concepts for discussion include the following:

Form	Key Processes	Notes
Nitrogen Gas (N2)	Nitrogen Fixation	Nitrogen gas is the most abundant gas in the atmosphere but not readily available in this form. Nitrogen fixation can be driven through atmospheric phenomenon such as lightning strikes or by special bacteria in the soil which form a symbiotic relationship with plants such as legumes.
Ammonia-Nitrogen (NH3)/Ammonium-Nitrogen (NH4)	Ammonification	This form of nitrogen occurs from animal wastes and organic decay. Bacteria and other decomposers convert (i.e. mineralize) these complex organic wastes into the more useable

		forms of ammonia/ammonium through the process of ammonification.
Nitrite-Nitrogen (NO2)	Nitrification	Special types of bacteria perform the two-step process of nitrification to convert ammonia/ammonium into the plant useable form of nitrate-nitrogen (NO3). The first step occurs when ammonia-oxidizing bacteria convert ammonia into nitrite-nitrogen (NO2). The second step occurs when nitrite-oxidizing bacteria convert NO2 into NO3. The entire nitrification process requires plenty of oxygen.
Nitrate-Nitrogen (NO3)	Assimilation/Denitrification	NO3 travels readily with water and plant roots take up NO3 through the process of assimilation. Unlike nitrification, denitrification occurs when oxygen is lacking (e.g. saturated soils, bottoms of ponds and wetlands). Here a another special type of bacteria converts NO3 back into N2 gas released into the atmosphere to complete the cycle.

4.1.3 Activity – 20 minutes

At the end of the discussion on the nitrogen cycle the teacher should pass around fertilizer labels among the students. The teacher should ask the question: In what forms does nitrogen from fertilizer come?

The teacher should instruct each student to draw their own nitrogen cycle in their STEAM Research Notebooks. This cycle should be based on a typical greenhouse that has growing plants. Students can use multiple colors and illustrations to highlight the various inputs of nitrogen and their forms and what processes are occurring to change nitrogen forms or allow for assimilation by plants.

4.1.4 Wrap-Up – 5 minutes

In the final five minutes of this session the teacher should ask for a few volunteers to describe their nitrogen cycles. The class can discuss how nitrogen is being managed within a greenhouse system.

4.1.5 Deliverables

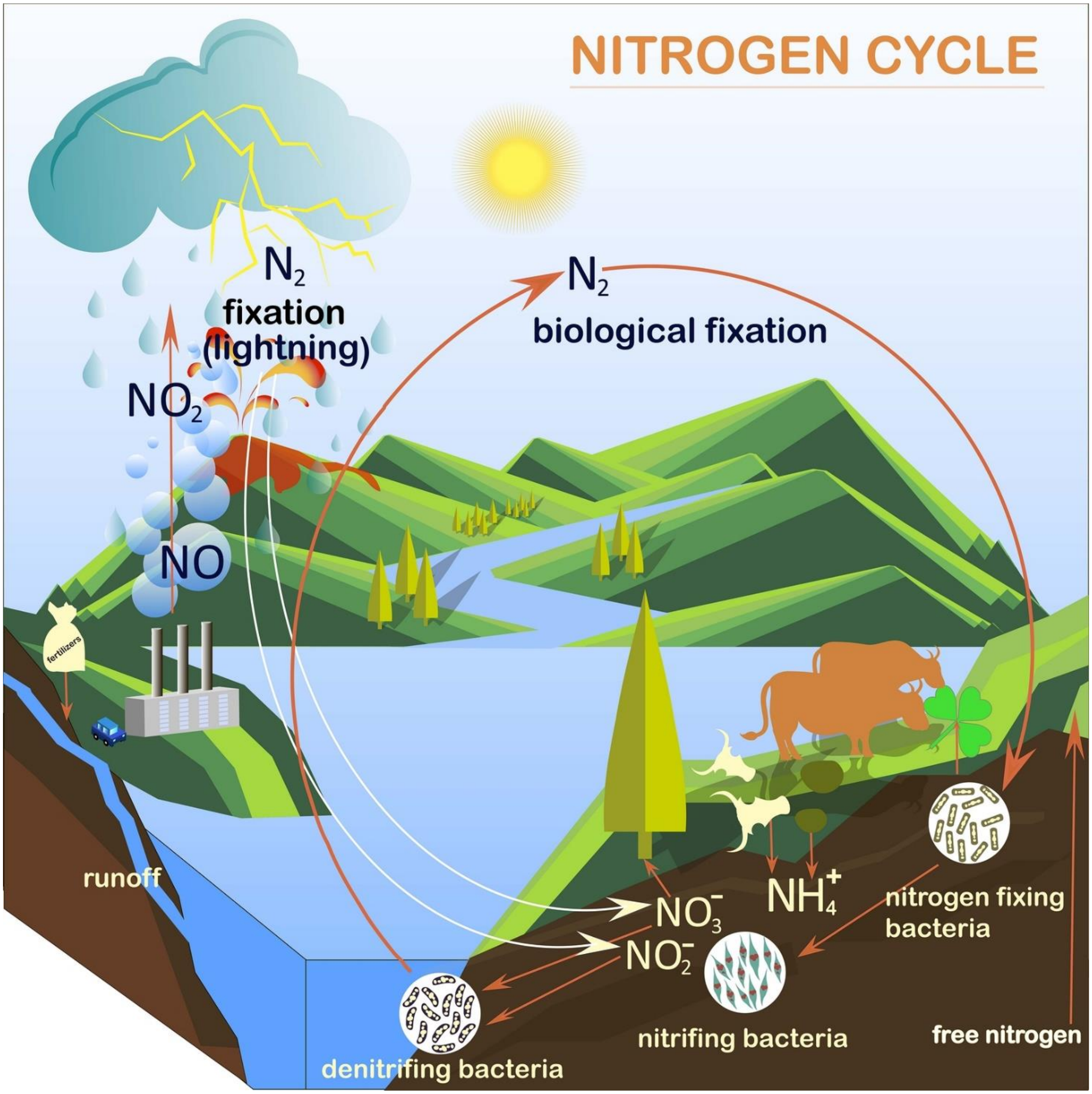
At the end of this session the students should have completed the following:

- Drawn their own nitrogen cycle for a greenhouse system in their STEAM Research Notebook

4.1.6 Supplemental Session Resources

Nitrogen Cycle

Figure 4.1.1: Nitrogen Cycle Handout



https://www.bigstockphoto.com/image-187978867/stock-vector-scheme-of-the-nitrogen-cycle%2C-flats-design-vector-illustration

4.2 Supplemental Session Two – Phosphorus Cycle – 40 minutes

In this Supplemental Session, students will explore the phosphorus cycle further to better understand concepts and dynamics in how phosphorus moves through controlled environment agriculture systems. Students will work individually to diagram their own phosphorus cycles for a greenhouse system.

4.2.1 Teacher Preparation, Supplemental Session One

The teacher should review The Phosphorus Cycle article from the Science Learn Hub and preview the Phosphorus Cycle handout and Phosphorus Cycle video. Handouts should be printed for each student and the teacher should prepare any audio/video equipment that will be used to show the Phosphorus Cycle video in class.

Teacher Materials:

The Phosphorus Cycle. Science Learning Hub. https://www.sciencelearn.org.nz/resources/961-the-phosphorus-cycle

Digital Resources:

Phosphorus Cycle Video: https://youtu.be/_IBx0zpNoEM

Student Materials:

STEAM Research Notebook

Pen or Pencils (multiple colors)

Handouts:

Phosphorus Cycle

Table 4.2 Explicit Knowledge Required for Supplemental Session

Core Area	Knowledge Required	Supports for Student Learning

Science	Students should understand that plants require nutrients to live and grow.	Students will develop their own phosphorus cycles based on the provided handout and video.
	Students should understand that plants acquire their material for growth chiefly from air and water, and that matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment.	The teacher will provide background knowledge and examples about controlling factors in plant growth, biogeochemical cycling, and CEA systems
Language Arts	Students should be able to explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical, scientific, or technical text based on specific information in the text.	Teacher will model and provide examples of applying information from images, illustrations, experiments, and text to draw connections between concepts.

4.2.2 Introduction – 15 minutes

The teacher should start this session by asking questions such as: What are other important nutrients, besides nitrogen, that plants need to grow? Where do plants get these nutrients? How do these nutrients move through air, soil, and water? Are these pathways different than what we find in the nitrogen cycle? This introduction should highlight that phosphorus, along with nitrogen, is a key nutrient in plant growth and is needed by all living organisms for processes such as energy production (i.e how our bodies metabolize and make energy) and to make things like the DNA that our bodies use to function. Following a brief discussion, the teacher should distribute the Phosphorus Cycle handout to each student in the class. Once handouts are distributed, the teacher should start the Phosphorus Cycle video. Following the video, the class should spend approximately 10-12 minutes discussing the primary forms and processes within the Phosphorus Cycle handout. Questions for discussion may include:

- How does phosphorus exist naturally within the environment? [Answer: Long-term phosphorus storage is primarily within rocks. A relatively small amount is held within soils, water, and plants.]
- How is phosphorus made available to plants? [Answer: Weathering of rocks release phosphorus naturally to soil and water. Humans also mine phosphorus from rocks and make fertilizers which are applied to crops.]
- What are some ways that the Phosphorus Cycle is similar to the Nitrogen Cycle? [Answer: Phosphorus and nitrogen can both be recycled (i.e. mineralized) from wastes and organic matter by bacteria and decomposers. When present in excess amounts both nitrogen and phosphorus can be “lost” from the soil and end up in lakes and oceans.]
- What are some ways that the Phosphorus Cycle is different from the Nitrogen Cycle? [Answer: Phosphorus does not have an atmospheric form like nitrogen, so excess phosphorus is harder to remove from the landscape.]

- What happens if humans run out of mineable phosphorus? [Answer: Open for discussion. Once mineable phosphorus becomes limited, prices of fertilizer will likely rise drastically and there may be a shift back to using natural, organic forms of fertilizer.]

4.2.3 Activity – 20 minutes

At the end of the discussion on the phosphorus cycle the teacher should instruct each student to draw their own phosphorus cycle in their STEAM Research Notebooks. This cycle should be based on a typical greenhouse that has growing plants. Students can use multiple colors and illustrations to highlight the various inputs of phosphorus and what processes are occurring to cycle.

4.2.4 Wrap-Up – 5 minutes

In the final five minutes of this session the teacher should ask for a few volunteers to describe their phoshporus cycles. These students should be different than those that volunteered to describe their nitrogen cycle illustrations. The class can discuss how phosphorus is being managed within a greenhouse system.

4.2.5 Deliverables

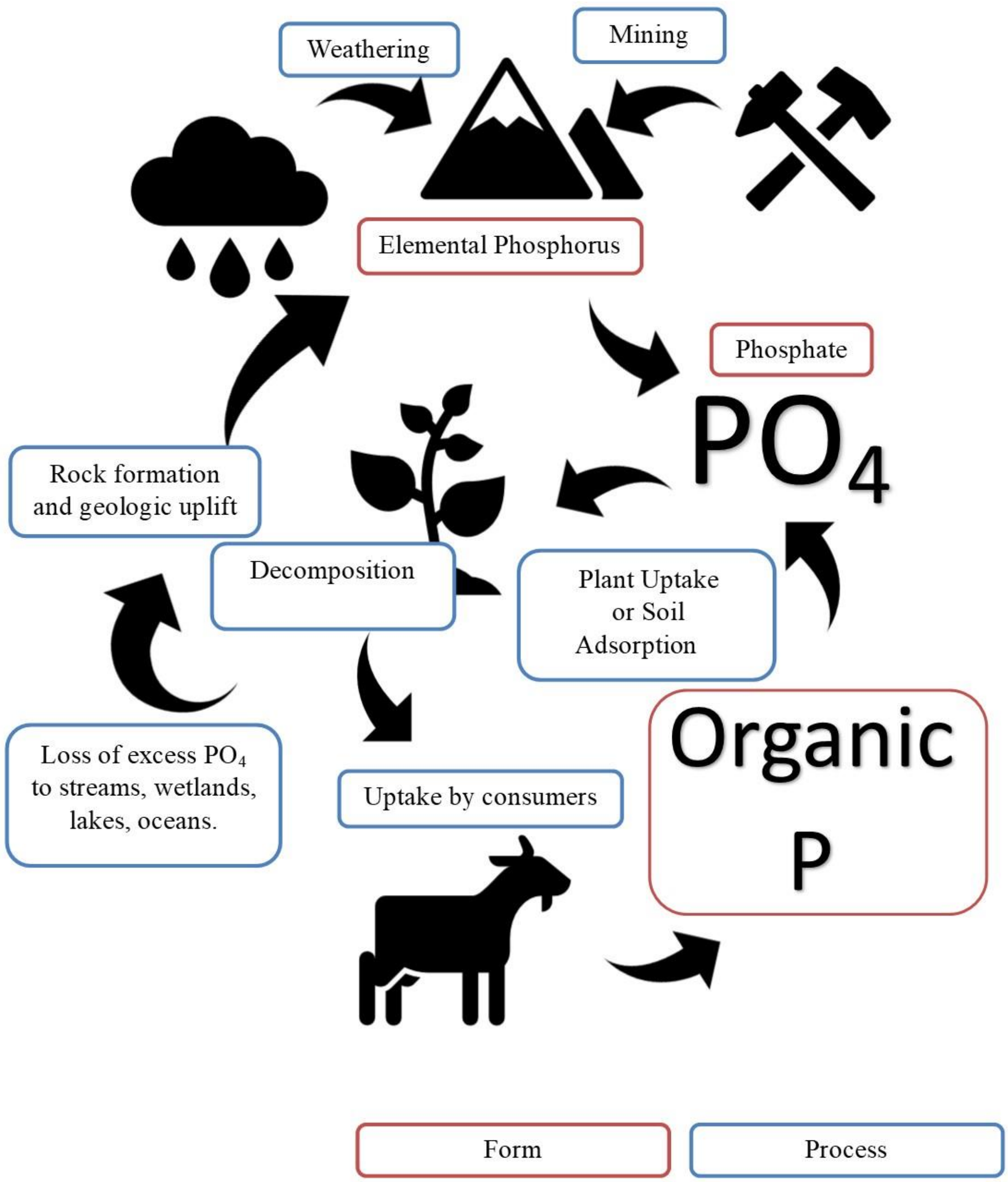
At the end of this session the students should have completed the following:

- Drawn their own phosphorus cycle for a greenhouse system in their STEAM Research Notebook

4.2.6 Supplemental Session Resources

Phosphorus Cycle Handout

Figure 4.2.1 Phosphorus Cycle Handout



4.3 Supplemental Session Three – Carbon Cycle – 40 minutes

In this Supplemental Session, students will explore the carbon cycle further to better understand concepts and dynamics in how carbon drives production and moves through controlled environment agriculture systems. Students will work individually to diagram their own carbon cycles for a greenhouse system.

4.3.1 Teacher Preparation, Supplemental Session One

The teacher should review the Carbon Cycle articles from Science Learn Hub and The Environmental Literacy Group. Teachers should also preview the Carbon Cycle handout and Carbon Cycle video. Handouts should be printed for each student and the teacher should prepare any audio/video equipment that will be used to show the Carbon Cycle video in class.

Teacher Materials:

The Carbon Cycle. Science Learning Hub. https://www.sciencelearn.org.nz/image_maps/3-carbon-cycle

Carbon Cycle. The Environmental Literacy Group. https://enviroliteracy.org/air-climate-weather/biogeochemical-cycles/carbon-cycle/

Digital Resources:

Carbon Cycle Video: https://youtu.be/K-EFS2p9ToA

Student Materials:

STEAM Research Notebook

Pen or Pencils (multiple colors)

Handouts:

Carbon Cycle

Table 4.2 Explicit Knowledge Required for Supplemental Session

Core Area	**Knowledge Required**	**Supports for Student Learning**
Science	Students should understand that plants require nutrients to live and grow.	Students will develop their own carbon cycles based on the provided handout and video.
	Students should understand that plants acquire their material for growth chiefly from air and water, and that matter cycles between the air and soil and among plants, animals, and microbes as these organisms live and die. Organisms obtain gases, and water, from the environment, and release waste matter (gas, liquid, or solid) back into the environment.	The teacher will provide background knowledge and examples about controlling factors in plant growth, biogeochemical cycling, and CEA systems
Language Arts	Students should be able to explain the relationships or interactions between two or more individuals, events, ideas, or concepts in a historical,	Teacher will model and provide examples of applying information from images, illustrations, experiments, and text to draw connections

	scientific, or technical text based on specific information in the text.	between concepts.

4.3.2 Introduction – 20 minutes

The teacher should start this session by describing that carbon is the most fundamental building block of living things on this Earth. Teachers should describe that it's in the air we breathe, the food we eat, the fuel that powers most of the world, and even plays a role in regulating Earth's climate and temperature.

Following a brief discussion, the teacher should distribute the Carbon Cycle handout to each student in the class. Once handouts are distributed, the teacher should start the Carbon Cycle video.

Following the video, the class should spend approximately 10-12 minutes discussing the primary forms and processes that move carbon between the primary reservoirs; soil and rocks and fossil fuels, ocean, atmosphere, and living organisms. Questions for discussion may include:

- Where is carbon stored? What are the primary reservoirs of carbon? [Answer: Carbon is largely stored with the atmosphere, ocean, living organisms, and fossil fuels.]
- What is the key process for primary plant production that converts atmospheric carbon (i.e. CO_2) into biological forms of carbon? [Answer: Photosynthesis! Plants take in CO_2 and water to make food.]
- How does carbon cycle through living organisms? [Answer: Plants take in CO_2 from the atmosphere to grow. Carbon from these plants are taken in by consumers to grow as well. During respiration, CO_2 is released back into the atmosphere. Decomposers return carbon from plants and animals back to organic matter in the soil and water. This happens on both land and water.]
- How does carbon cycle through non-living systems? [Answer: Carbon in the soil and bottom sediments of wetlands, lakes, or oceans go through the process of deposition to form things such

as fossil fuels and rocks. Volcanic eroputions expel deposited carbon back into the atmostphere. Land erosion (of soil and organic matter) transports carbon from places higher up in the landscape to places lower in the landscape.]

- How do humans impact the carbon cycle? [Answer: Through the burning of fossil fuels humans release carbon back into the atmosphere.]

4.3.3 Activity – 20 minutes

At the end of the discussion on the carbon cycle the teacher should instruct each student to draw their own carbon cycle in their STEAM Research Notebooks. This cycle should be based on a typical greenhouse that has growing plants. Students can use multiple colors and illustrations to highlight the various inputs of carbon and what processes are occurring to cycle.

4.3.4 Wrap-Up – 5 minutes

In the final five minutes of this session the teacher should ask for a few volunteers to describe their carbon cycles. These students should be different than those that volunteered to describe their nitrogen and phosphorus cycle illustrations. The class can discuss how carbon is being managed within a greenhouse system.

4.3.5 Deliverables

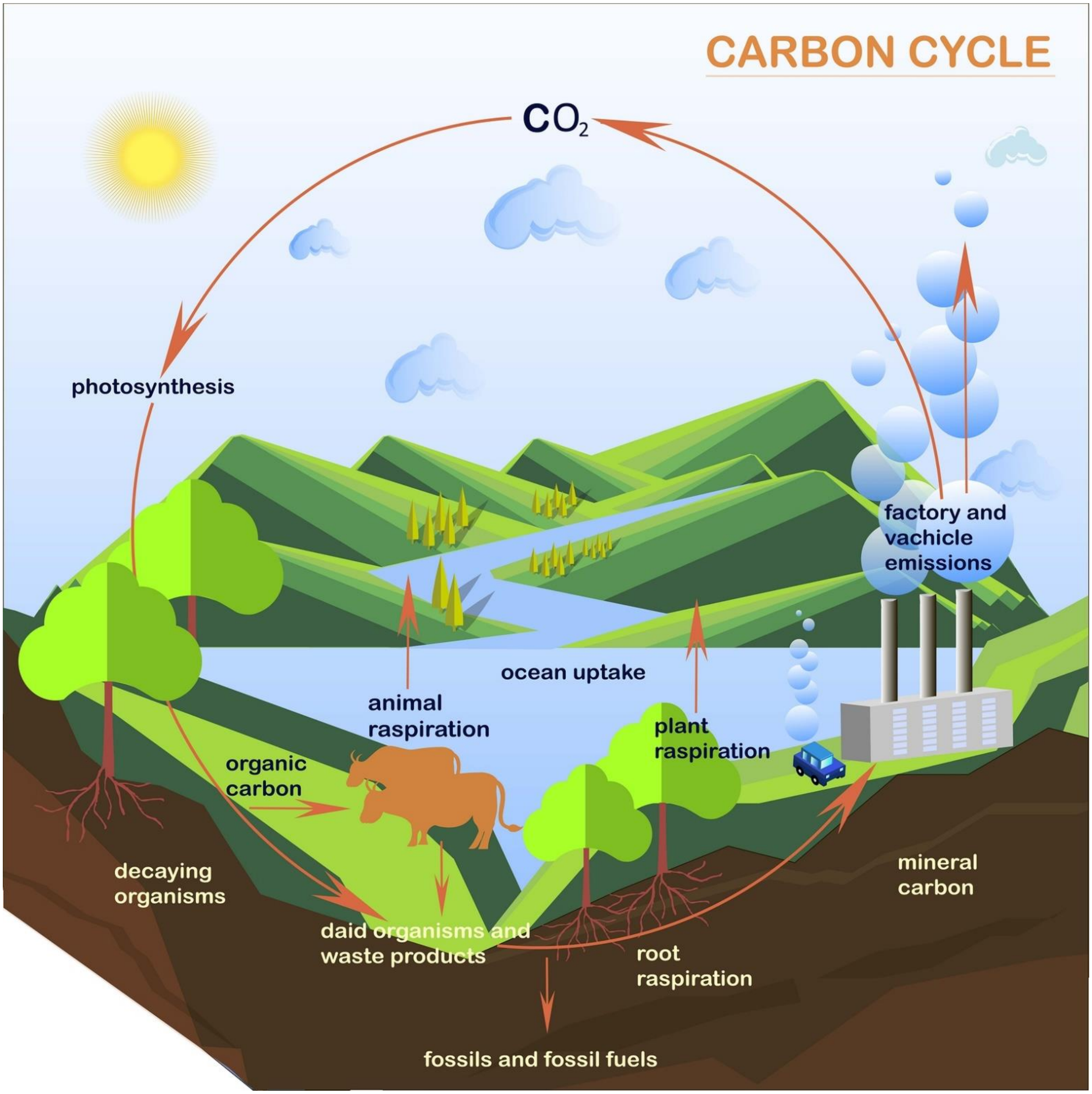
At the end of this session the students should have completed the following:

- Drawn their own carbon cycle for a greenhouse system in their STEAM Research Notebook

4.3.6 Supplemental Session Resources

Carbon Cycle

Figure 4.3.1: Carbon Cycle Handout



https://www.bigstockphoto.com/image-190117396/stock-vector-scheme-of-the-carbone-cycle%2C-flats-design-vector-illustration

5.0 Appendix B – Teacher Resources

5.1 Vocabulary

The following vocabulary words are provided for your reference. You may choose to introduce some or all vocabulary terms to students.

Term	Definition
absorption	the process or action by which one substance takes up, or absorbs, another
agroecosystem	the organisms and environment of an agricultural area considered as an ecosystem
axis	an imaginary line around which an object rotates
biodiversity	the variety of life in the world or in a particular habitat or ecosystem
biogeochemical cycle	a pathway by which chemical elements and compounds move through biotic (biosphere) and abiotic (lithosphere, atmosphere, and hydrosphere) spheres of Earth
budget	an estimate of income and expenditure for a set period of time
Celsius	a temperature scale in which water freezes at 0-degrees and boils at 100-degrees
climate	the weather conditions prevailing in an area in general or over a long period
climate change	a long-term change in global or regional climate patterns; often refers to changes attributed to increases in atmospheric chemicals such as carbon dioxide as a result of the widespread use of fossil fuels
computer-aided drafting (CAD)	the use of computer programs to create, modify, and/or analyze a design
constraint	a limitation or restriction
control variable	the element that is not changed in an experiment to allow the relationship between the other variables to be tested
controlled-environment agriculture (CEA)	Using technology to create optimal growing conditions within an enclosed structure such as a greenhouse.
convention	a way in which something is usually done, especially within a particular discipline

cooperate	working together toward a common goal
cultural (ecosystem service)	Cultural benefits that humans experience based upon the natural environment. Examples include the use of nature in books and art and in therapeutic activities.
degrees	the unit used to measure temperature and angles
delegate	dividing tasks in order to accomplish a shared group goal
dependent variable	a variable (often denoted by y) whose value depends on that of another
design	the process of synthesizing knowledge and creativity to create a solution to a problem or challenge
economy	the system of money and resources in an area involving the production and consumption of goods and services
ecosystem	a community of living things and their interaction with their physical environment
ecosystem services	the benefits that humans experience as a result of being exposed to a healthy natural environment
engineering design process (EDP)	a process used by engineers and other professionals to design solutions to problems or to design new or improved products
experiment	An investigation often undertaken by scientists, to test ideas or demonstrate known concepts
Fahrenheit	a temperature scale in which water freezes at 32-degrees and boils at 212-degrees
fertilizer	a chemical or natural substance added to soil to increase its nutrient value for plants
global awareness	interacting with people from various cultures, religions, and lifestyles in a learning-centered and respectful way
greenhouse	a building in which plants are grown to protect them from natural weather and climate conditions
horizontal	lying flat or in the same direction as the ground
human system	Systems created by humans to structure interactions between people (e.g. economic systems, social networks, political structures, etc.).

hydroponics	the process of growing plants without soil in a liquid medium that provides nutrients to the plants.
hypothesis	a proposed explanation for a phenomenon that can be tested
independent variable	a variable (often denoted by x) whose variation does not depend on that of another
landscape	the visible features of an area seen when looking over an area from a distance
landscape orientation	arranged in a horizontal way; when a page is wider than it is tall
latitude lines	east-west circles on a globe that are parallel to the equator; used to measure north-south positions
limitation	something that controls what is possible by setting boundaries
longitude lines	north-south lines on a globe; used to measure east-west positions
mean	a number expressing the average of a data set, calculated by dividing the sum of the values in the set by the number of data points in the set
median	a number expressing the midpoint of a data set so that there is an equal probability of the values in the set falling above or below it
mode	a number expressing the value that occurs most frequently in a data set
model	a description (can be an object, a visual representation, or mathematical representation) of an object or a phenomenon that includes important features of the object or phenomenon
natural resources	materials or substances that occur in nature and can be used by humans
natural system	systems that occur in nature (e.g. circulation of water in the ocean, weather and climate, water drainage, etc.)
nutrient	a substance that provides nourishment essential for an organism's survival and growth

obstacle	an event or situation that stands in the way of achieving a goal
opportunity	a situation or set of circumstances that makes it possible to do something or progress toward a goal
outlier	a data point in a data set that is very much bigger or smaller than the next nearest data point
photosynthesis	a process used by plants to synthesize food using sunlight, carbon dioxide and water; generally generates oxygen as a byproduct.
portrait orientation	arranged in a vertical way; when a page is taller than it is wide
precipitation	rain, snow, sleet, or hail that falls to the ground
problem	a situation that needs to be overcome or fixed
prototype	a simplified, working model of a machine or process
provisioning (ecosystem service)	material benefits from the outputs from ecosystems such as food, water and other resources.
reflection	thinking and writing about a topic or previous work
regulating (ecosystem service)	the benefits that ecosystems provide by regulating the natural environment; include waste decomposition, water and air purification, flood prevention, and pest and disease control.
resilience	the capacity to recover quickly from difficulties; toughness
resource	person or thing that can help in achieving a goal
revolve	to move in a circular path around another object
rotate	to move in a circle (spin) around an imaginary centerline (or axis)
rubric	a guide for evaluating a student’s work
scale	a set of numbers used to measure or compare the level of something
scenario	an proposed sequence or development of events

season	the four divisions of the year typified by weather patterns and number of daylight hours
soil	the loose upper layer of earth, composed of a mixture of organic remains, clay, and rock particles, in which plants grow
solar radiation	radiant energy emitted by the sun, particularly electromagnetic energy
supporting (ecosystem service)	services the ecosystem provides that make life on earth possible, such as nutrient cycling and wildlife habitats
sustainable agriculture	producing food, fibers, and other plant or animal products in a way that does not endanger the ability of future generations to meet their needs
table of contents	the section of a book where all items in the book are listed along with their location (page number)
teamwork	combined action of people working together to achieve a common goal
thermometer	an instrument for measuring temperature
tilt	a sloping position or movement
transmittance	the effectiveness of a surface in transmitting radiant energy
variability	lack of consistency or fixed pattern; liability to vary or change
vertical	straight up and down
weather	the state of the atmosphere in a particular time and place; includes heat, dryness, sunshine, wind, rain

5.2 Learning Supports for Students

Graphic Organizers for Organizing the Notebook and Writing

Help your students organize and communicate all or parts of their research more effectively by using graphic organizers, templates, and foldables. Many types of graphic organizers guide students to find relationships. Some examples are:

- **Cluster Map:** a way to think of new ideas. Words or phrases are listed inside a large shape, then connections are made and written in smaller circles or shapes that are connected with a line.
- **Cluster Web:** a wheel of connecting details around a single topic.
- **Concept Map:** show students how ideas are connected using images and arrows.
- **Fishbone chart:** this is also called a "cause and effect diagram." This is a type of graphic organizer used to explore many aspects or effects of a complex topic, helps student to organize their thoughts in a simple, visual way. Using color helps make the fishbone map clearer and easier to interpret.
- **Four Squares:** a simple layout of ideas to be used during sorting activities. Many people use it for brainstorming or forming teams.
- **Hand Map:** Sometimes called the "Five Things You Need to Know" map. Great way to prepare for writing an essay by placing the main idea in the palm of the hand and supporting details on each finger.
- **Idea Wheel:** an organizer that can be used as a web or a cycle to show a series of events or connections; write or draw ideas in each section
- **Inverted Triangle:** A way to narrow down the topic to get a focused idea. This is also used to collect ideas by writing the information that MUST be known on the top line, then a subgroup of additional information that is helpful but not crucial on the next, and continue to break down the topic in each line below.
- **Know/Wonder/Learn (KWL) Chart:** Used to spark the creative side using inquiry. The class completes this chart with a new lesson or unit. This chart contains a title or topic and three columns, one each for "What we know," "What we wonder/want to know," and "What we

learned.” It should be introduced as a new topic is introduced and filled in throughout the lesson or unit.

- **Main Idea Map:** Provides support or back up for a main idea with evidence in the form of supporting details. Multiple maps can be used to build off one another.
- **Observation Chart:** Use to organize observations based on the five senses.
- **T-Chart:** a chart used to list and examine two facets of a topic, such as the pros and cons, advantages and disadvantages, or facts and opinions.
- **Venn diagram:** Used to compare themes, topics, or concepts.

5.3 STEAM Careers Connected with This Unit

Various STEAM careers can be emphasized in each of the STEAM Plus units. There are a variety of ways you can include career connections, including having members of teams assume roles as professionals of one of the careers related to the unit topic. For this unit, the following are examples of related careers:

> **Environmental Engineer:** Environmental engineers are concerned with protecting people from the challenges posed by adverse environmental factors such as pollution or hazardous waste runoff. Their primary concern is to improve the environment through recycling, waste disposal, public health, water quality, and air pollution control.
>
> **Media Artist:** Media artists combine forms of art by recording sounds or visual images to communicate a message. This may include computer animations, digital arts, graphic design, video games, computer robotics, and 3D printing.
>
> **Botanist:** Botanists are plant scientists. They may look for new species of plants and even create new plants using a technique called “grafting.” Botanists might also study the effects

of environmental conditions such as acid rain on plants or look for ways to grow plants in small spaces using strategies such as terraces and hydroponics.

Meteorologist: Meteorologists are trained in high level mathematics and science and often computer programming. They apply these skills to observe and explain how the atmosphere affects the earth and life on our planet. Meteorologists may forecast the weather and report on weather events such as hurricanes, tornadoes, heatwaves, and blizzards. There are several settings in which meteorologists might work. For example, meteorologists might work as news weathercasters, researchers, teachers, consultants, or climate specialists.

Agroecologist: Agroecologists are experts in the study and application of ecological processes applied to agricultural production systems. Agroecologists may experiment and apply agricultural principles and practices that, over the long term, enhance environmental quality, make efficient use of nonrenewable resources, integrate natural biological cycles and controls, and are economically viable and socially responsible

Agricultural worker: Agricultural workers maintain the quality of farms, crops, and livestock by operating machinery and doing physical labor under the supervision of farmers, ranchers, and other agricultural managers. They may harvest and inspect crops by hand, irrigate farm soil and maintain ditches or pipes and pumps, and/or many other important duties on the farm.

Architect: Architects work in the construction industry designing new buildings, restoring and conserving old buildings and developing new ways of using existing buildings. They are involved in construction projects from the earliest stages through to completion.

Agricultural & Biological Engineer: Agricultural and Biological engineers apply knowledge of engineering technology and biological science to agricultural problems concerned with power and machinery, electrification, structures, soil and water conservation, and processing of agricultural products.

Science Teacher: A science teacher not only helps answer questions, they inspire their students to seek out the answers for themselves. A science education includes subjects such as chemistry, physics, biology, marine science, astronomy and other courses on the physical sciences. They create lesson plans; evaluate student performances; and teach using lectures, technology and hands-on learning experiences.

Natural Resource Manager: Natural resources management is the general management of lakes, forests, plants, soil and other natural resources. Natural Resource Managers provide leadership and oversight to conservation and environmental management projects, such as protecting property from over-development or planning for effective, sustainable land use.

Technical Writer: Technical writers, also called technical communicators, prepare instruction manuals, journal articles, and other supporting documents to communicate complex and technical information more easily. They also develop, gather, and disseminate technical information among customers, designers, and manufacturers.