Grade: 6-8	**Topic:** Hydroponics	**Lesson (Number/Title):** Building and Assessing an Indoor Vertical Hydroponics Farm

Brief Lesson Description:

Students will be introduced to the concepts of indoor vertical gardening and hydroponics as solutions to challenges facing food production in parts of our world. Through the study of various hydroponic growing methods, students will gain an understanding of the variables that prove most critical for the success of the system. They will also develop an appreciation for how to monitor and control these variables while utilizing hydroponic methods. Finally, students will compare the different hydroponic methods to traditional farming in soil and consider the pros and cons of each style.

Performance Expectations:

MS-LS1-5. Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

MS-LS2-1. Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

MS-ESS3-3.Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ESS3-4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

MS-ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Specific Learning Outcomes:

- Students will identify the resources that plants require from their environment in order to survive.
- Students will explain the role of the leaves, stems, and roots in acquiring these resources from the environment.
- Students will compare qualitative and quantitative data to determine which design is most effective.
- Students will communicate their results with one another in order to identify the aspects of their models that should be carried forward and those that should be eliminated.
- Students will use the graphical representation of data to draw conclusions about their designs.

Narrative/Background Information:

Background for Teachers:

One of the many challenges facing an ever growing human population is the problem of food production. Suitable farmland is being diminished by urban expansion. Unpredictable climate patterns are shortening or making growing seasons more harsh. Irrigation concerns related to scarcity or contamination are putting a premium on clean water as an accessible resource. Science and engineering will be called upon to combat these concerns. A new wave of indoor vertical farms is allowing us to produce food in otherwise inhospitable growing environments. Congested urban cities; oppressive desert and arctic climates; even the prospect of growing food on orbiting space stations or other planets is within reach.

As part of this lesson, students will gain an appreciation for the resources necessary to grow crops, the variables that must be controlled, and the obstacles involved with growing in such remote locations.

Teacher's Preparation:

- Plastic bottles (size of your choosing) should be collected ahead of time, rinsed, and have their labels removed. Retain the caps. (Models A and B)
- PVC pipe, fittings, and glue may be needed if you wish to build Model C in the tutorial.
- You should review the attached bill of sale to determine the scope of your participation. Model D will require a few specialized components to help compare reservoir size and variable stability.
- If you intend to start from seed, be sure to have all necessary seed starting equipment prior to introducing the lesson.
- You should select a leafy green you would like to experiment with and acquire seeds.
- Seeds should be sewn at least two weeks in advance of implanting them into their systems. If you intend to start the soil control group in their own pots, do so at the same time that you prepare the hydroponic rockwools.
- Any students that handle the rockwools should wear non-latex gloves, protective eye wear, and should avoid shredding the material so that it is not inhaled.
- Designate a spot in your classroom/greenhouse that will provide ample light for your plants or prepare a growing area that will be equipped with indoor grow lights. You may wish to purchase or construct an apparatus that will act as a shelving system for your vertical growing environment. Be sure to select strong building materials as the water in the reservoirs can become quite heavy.
- Hydroponic solutions will need to be prepared with the appropriate pH and nutrient concentrations. Instructions will be included in the tutorial series. You may wish to do this yourself or select trusted student volunteers. Proper skin and eye protection should always be used when handling liquid nutrients or pH adjustment solutions.

Prior Student Knowledge:

- Students should have an understanding of photosynthesis in terms of its reactants and products.
- Students should be able to label basic plant anatomy and explain its role in acquiring reactants or distributing products.
- Students should grasp sound experimental design and be able to apply the concepts of experimental vs control groups, independent vs dependent variables, and limiting confounding variables.
- Simple measurements should be able to be organized into properly labeled data tables.
- Data tables should be able to be converted into line graphs for analysis and read for relationships between the independent and dependent variables.
- Unit conversions should be able to be executed by manipulating simple proportions.
- Proper research procedures should be covered for using online search engines and polling information sources for their validity.

Science & Engineering Practices:	Disciplinary Core Ideas:	Crosscutting Concepts:
Constructing Explanations and Designing Solutions Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific knowledge, principles, and theories. (LS1-5), (ESS3-3) Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. (LS1-5) Apply scientific principles to design an object, tool, process or system (ESS3-3) **Analyzing and Interpreting Data** Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. (LS2-1), (ETS1-3) Analyze and interpret data to provide evidence for phenomena. (LS2-1) Analyze and interpret data to determine similarities and differences in findings. (ETS1-3) **Engaging in Argument from Evidence** Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s). (LS2-4), (ESS3-4), (ETS1-2) Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. (LS2-4), (ESS3-4) Evaluate competing design solutions based on jointly developed and agreed- upon design criteria. (ETS1-2) **Asking Questions and Defining Problems** Asking questions and defining problems in grades 6–8 builds on grades K–5 experiences and progresses to specifying relationships between variables, and clarifying arguments and models. (ETS1-1)	**LS1.B: Growth and Development of Organisms** Genetic factors as well as local conditions affect the growth of the adult plant.(LS1-5) **LS2.A: Interdependent Relationships in Ecosystems** Organisms, and populations of organisms, are dependent on their environmental interactions both with other living things and with nonliving factors. (LS2-1) In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. (LS2-1) Growth of organisms and population increases are limited by access to resources. (LS2-1) **LS2.C: Ecosystem Dynamics, Functioning, and Resilience** Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (LS2-4) **ESS3.C: Human Impacts on Earth Systems** Typically as human populations and per-capita consumption of natural resources increase, so do the negative impacts on Earth unless the activities and technologies involved are engineered otherwise. (ESS3-3), (ESS3-4) **ETS1.A: Defining and Delimiting Engineering Problems** The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (ETS1-1) **ETS1.B: Developing Possible**	**Cause and Effect** Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. (LS1-5) Cause and effect relationships may be used to predict phenomena in natural or designed systems. (LS2-1), (ESS3-4) Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.(ESS3-3) **Stability and Change** Small changes in one part of a system might cause large changes in another part. (LS2-4) **Influence of Science, Engineering, and Technology on Society and the Natural World** The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time. (ESS3-3), (ETS1-1) All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (ESS3-4), (ETS1-1)

Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. (ETS1-1) **Developing and Using Models** Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. (ETS1-4) Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs. (ETS1-4)	**Solutions** There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (ETS1-2), (ETS1-3) Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (ETS1-3) A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (ETS1-4) Models of all kinds are important for testing solutions. (ETS1-4) **ETS1.C: Optimizing the Design Solution** Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. (ETS1-3) The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (ETS1-4)	

Possible Preconceptions/Misconceptions:

- Plants require soil in order to perform photosynthesis.
- Light must come from the sun in order for plants to get enough energy to grow.
- Plants use oxygen from the atmosphere around them.
- All acidic substances are harmful to living things.
- The more nutrients given to a plant, the more successful it will be.
- Soil must be packed tightly around the root base of a plant.
- Radiation from the sun is safe in space.

LESSON PLAN: 5-E Model

ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions

Students will be engaged in a discussion about the concept of establishing an extraterrestrial space colony and terraforming another planet. Some may wish to show a short video clip from the film "The Martian" to stimulate interest. The opening focus should be on the basic necessities required by humans making this leap. Food, air, and water will all be viable responses.

This should be linked back to the role of plants and the importance of establishing successful crops in these new living environments. Emphasis should be placed on their being the start of the food chain, their ability to purify the air, and their ability to recycle both organic and water wastes produced by humans. With this being said, the discussion may now be directed toward the challenges in supporting a successful crop in these environments. What will plants require and why will it be difficult to supply these things on Mars? What makes it difficult to bring these resources with you as a space traveler?

EXPLORE: Lesson Description -

Day 1

1. After the opening discussion, students will be asked to complete the fields on their worksheet related to the needs of plants and the difficulties for accommodating them in space Table A. Areas of emphasis will include water, air, light, nutrients, and a suitable growing medium. Students may be required to use an online resource to complete this section. Answers should be reviewed and discussed.
2. A brief discussion about indoor vertical hydroponic farming should follow. Points of emphasis should include a small spatial footprint, ability to grow without soil, use less water, avoid contaminants and pestilence associated with traditional soil (insect, fungus, pollutants), and accelerated growth rates.
3. Introduce students to the various systems they will be building and observing over the coming weeks (wick, drip, and deep well systems). They should be helped to understand the mechanism by which each works. This will be covered in the accompanying tutorials.

Day 2

4. Students should be placed into design teams to create one of the three simple systems (A-C) following the tutorials provided. The worksheet will walk them through making decisions about medium, wicks, reservoirs, and plant thinning. These should be filled with nutrient solution and implanted with seedlings. A seedling should also be placed in soil if not already done.
5. The instructor/students may wish to setup the deep well systems (D) for comparison. The number of cultures is up to your discretion based on space and light limitations.
6. Table B should be completed in the worksheet to give students an opportunity to review plant anatomy and help understand how their indoor farm will accomodate them.

Days 3-(14 to 21)

7. Over the determined growing period (2-3 weeks) students should make both quantitative and qualitative observations about their systems as well as their sample in soil. Daily temperature, pH, plant height, leaf number, and general appearance will be recorded. Nutrient reservoirs should be changed weekly.
8. It should be noted that top watering will be necessary on a daily basis for the first 7-10 days after transplant into the new systems.
9. Worksheets will guide students toward creating line graphs for the four measurable variables. Discussion questions will help students to evaluate their design.
10. Communication between lab groups will take place during this process for the purpose of comparison and design iteration for future endeavors.
11. Students will communicate via FlipGrid on a weekly basis to update each other and international peers about their progress.
12. You may wish to allow students to conduct a follow up experiment in which they apply design revisions to see if they allow for improvement.

Materials Needed:

- Empty 2L plastic bottles (or size of your choosing), caps pre-drilled and cuts started with a hobby knife
- PVC pipe cut to length and fittings(optional if choosing design C)
- See bill of sale and tutorial for Deep Well requirements.
- ¼ inch braided nylon rope
- Aluminum foil
- Spray paint (optional)

- Spray adhesive (optional)
- Scotch tape
- Pots/containers for plants grown in soil
- Potting soil
- Various hydroponic growing media (perlite, coconut coir, hydroton, rockwool)
- Seedlings (or seeds if starting on your own)
- Hydroponic nutrients (see bill of sale)
- pH adjustment solutions (see bill of sale)
- Thermometers
- Litmus paper for pH testing
- Rulers

Probing or Clarifying Questions:

1. What makes topsoil different from sand and gravel? Where does this organic material come from?
2. Why do environments in space lack these materials in their dirt?
3. What resources would be difficult to come by when growing plants in space?
4. What challenges would astronauts face while trying to grow a crop in space?
5. What benefits besides being a food source would plants provide?
6. How is reservoir volume related to temperature and pH stability?
7. How is the volume of water consumed by hydroponic plants compare to those grown in soil?
8. How does the yield from a hydroponic garden compare to that from soil?
9. How do the growing rates of these two methods compare to one another?

EXPLAIN: Concepts Explained and Vocabulary Defined

Teacher:
- Asks for justifications (evidence) and clarification from students to provide evidence for the variables they selected for in their models.
- Formally provides definitions, explanations, and new labels
- Vocabulary: Hydroponics, capillary action, photosynthesis, confounding variable, graphical relationships, rate of change

Students:
- Uses their recorded observations in explanations
- Listens critically to others' explanations.
- Analyze graphical relationships to determine the relationships between variables
- Interpret data to determine flaws in their experimental design
- Iterate their design for future testing

ELABORATE: Applications and Extensions

Teacher:
- Refers students to existing data and evidence and asks: What do you already know? Why do you think…?

Students:
- On a blank sheet of paper, encourage students to draw and label their creation while in use.
- Regroup students with new partners and have students check for understanding with their peers and compare results.
- Students will use FlipGrid to communicate results and offer suggestions for design revisions.

EVALUATE: Formative Monitoring (Questioning / Discussion):

Teacher:

- Asks open ended questions such as: Why do you think….? How would you explain…? What evidence do you have?

Students:

- Answers open ended questions by using observations, evidence, and previously accepted explanations.
- Asks related questions that would encourage future investigations.
- Students will communicate with peer groups in different countries to compare the crops they selected and the success in their design.

Summative Assessment (Quiz / Project / Report): End of Unit group quiz and virtual discussion with international partner classes.

Reflection:

Ask students to observe these concepts in real world applications and explain them using support from their recorded observations.

Common Core State Standards Connections:

ELA/Literacy -
RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts. (MS-LS1-5), (MS-LS2-1), (MS-LS2-4), (MS-ESS3-4), (MS-ETS1-1), (MS-ETS1-2), (MS-ETS1-3)

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. *(MS-LS1-5)*

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). (MS-LS2-1), (MS-ETS1-3)

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. (MS-ETS1-2), (MS-ETS1-3)

WHST.6-8.1 Write arguments to support claims with clear reasons and relevant evidence. (MS-LS2-4), (MS-ESS3-4)

WHST.6-8.2 Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. *(MS-LS1-5)*

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. *(MS-ESS3-3), (MS-ETS1-2)*

WHST.6-8.8 Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation. *(MS-ESS3-3), (MS-ETS1-1)*

WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and research. *(MS-LS1-5), (MS-LS2-4), (MS-ESS3-4), (MS-ETS1-2)*

RI.8.8 Trace and evaluate the argument and specific claims in a text, assessing whether the reasoning is sound and the evidence is relevant and sufficient to support the claims. *(MS-LS2-4)*

SL.8.5 Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.

(MS-ETS1-4)

Mathematics -
6.SP.A.2 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. *(MS-LS1-5)*

6.SP.B.4 Summarize numerical data sets in relation to their context. *(MS-LS1-5)*

6.RP.A.1 Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. *(MS-ESS3-3), (MS-ESS3-4)*

7.RP.A.2 Recognize and represent proportional relationships between quantities.*(MS-ESS3-3), (MS-ESS3-4)*

6.EE.B.6 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. *(MS-ESS3-3), (MS-ESS3-4)*

7.EE.B.4 Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. *(MS-ESS3-3), (MS-ESS3-4)*

7.EE.3 Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals), using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies. *(MS-ETS1-1), (MS-ETS1-2), (MS-ETS1-3)*

MP.2 Reason abstractly and quantitatively *(MS-ETS1-1), (MS-ETS1-2)*, *(MS-ETS1-3), (MS-ETS1-4)*

7.SP Develop a probability model and use it to find probabilities of events. Compare probabilities from a model to observed frequencies; if the agreement is not good, explain possible sources of the discrepancy. *(MS-ETS1-4)*

Notes for Future Reference: