LESSON PLAN: Save the Fruit!

Testing prototypes and using failure points to improve design solutions

Description:
During this math focused unit, students will create a device that is used to harvest fruit from a tree. They will then look at failure points in order to iterate their design. Finally, students will describe their device as a system and explain each of its components.

Grade Levels: 3-5	**Objectives:** Students will: • Create a device, identify the components of their device, and explain how each component contributes to the system. • Collaboratively build a device that will help solve the real-world problems of harvesting fruit from trees and preventing food waste. • Identify failure points in their design and explain iterations supported by data. • Compare different solutions to the design problem and use observations to iterate their design. • Evaluate the differences between monoculture and polyculture farming.
Duration: Five 60-Minute Sessions	**Standards Connections:** ***NGSS Performance Expectation (PE)*** 3-5 ETS1-3 • Plan and carry out fair tests in which variables are controlled and **failure points are considered to identify aspects of a model or prototype that can be improved.** ***NGSS Crosscutting Concepts (CCC)*** 3-5 2. Developing and Using Models • **Collaboratively** develop and/or **revise a model based on evidence** that shows the relationships among variables for frequent and regular occurring events. ***NGSS Science and Engineering Practices (SEP)*** 3-5 Systems and Systems Models • Students understand that a system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. **They can also describe a system in terms of its components and their interactions.**

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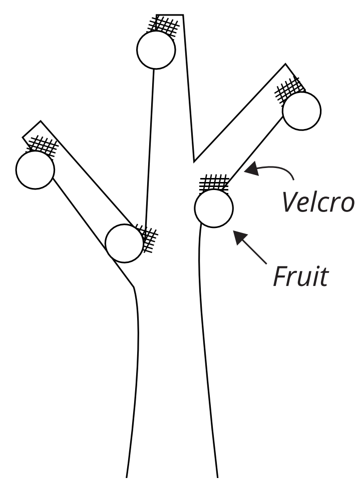
Materials:
Below are categories of materials for students to build with that include suggestions for types of items. Look around your classroom and school, or ask students to bring in the materials you all can use during the design challenge. Material quantities are for a class of 32 students, in teams of 2 to 4 students per team.

All Purpose Materials (200 total)	Connectors (200 total)
• Straws • 20 24-inch lengths of string • Rubber bands (1 bag) • 18"x18" Fabric squares	• Twist ties • Chenille stems (pipe cleaners) • Paper clips • Chip clips (assorted sizes)
Supports and Grabbers (50-100 total)	**Containers (50 total)**
• 12-18 inch wooden or plastic rods • Cardboard tubes • Utensils (forks, spoons, & knives) • Chopsticks	• Strawberry baskets (green) • Plastic bags • Rubber O-rings larger than the 'fruit' (to use with plastic bags)

Student Work Area Materials:
- 4-6 rolls of masking tape.
- 16 scissors.

Prep:
- Make a tree with fruit growing from high and low branches — you can do this in a variety of ways:
  - Make a cardboard tree and attach foam circles with velcro.
  - Draw a tree on butcher paper and attach pom-pom balls to the paper with tape.
  - Example image of a tree for this design challenge: Fruit Tree Image
  - Use a broom or long stick to attach student prototypes for testing.



- Prep tables & organize materials:
  - For tips on materials management and facilitation, visit [Tech Tip: Managing Materials.]
  - Example images of some materials tables: [materials table image] [materials table image 2]
- Students will be placed into teams of 2 to 4 students depending on class size, access to materials, and time constraints.
- Print handouts needed during unit: data collection, plant recommendation, assessment, and rubric.

Tech Tips:
These one-page guides provide tips and best practices for facilitating design challenges
- Managing Materials
- What is Engineering?
- Language of Engineering
- Prototyping
- Collecting Data
- Sharing Solutions

Lesson

A. Introduction (20 Minutes)

1. Introduce students to the environmental issue of coastal erosion by showing them videos.
    a. Lead a discussion about engineering using the Tech Tip: What is Engineering? as a resource.
    b. Tech Tip: The Language of Engineering has great ideas to support students' learning of the engineering vocabulary.

2. Lead a discussion about tools used on a farm and have students guess the function based on the components.
    a. Bring in tools for the students to touch and manipulate to build interest in the topic.
    b. For options and resources for this discussion see Appendix C: Resources - Farming.
    c. Possible facilitative questions:
        i. *What parts or **components** does this tool have?*
        ii. *What do you think this tool does based on its **components**?*
        iii. *If I wanted to plant a row of tomatoes, which tool or tools would I need? (Possible answers include: a shovel or spade, a hoe, a rake, gloves, tiller, watering hose or can, tomato cages.)*
    d. *In farming, different tools (physical tools, fertilizers, other plants, insects, water) can be used in different combinations or orders so that their **interactions** get a specific result (encouraging seed germination, sprouting, plant growth, fruiting or ripening).*

3. Build context and understanding of the importance of sustainable agricultural farming practices (**permaculture** farming) to help students engage with the design challenge.
    a. Show a video that explains permaculture farming. One possible video is "Permaculture - Mono vs Poly".
    M, Nicole. "Permaculture - Mono vs Poly." YouTube, 5 October 2013. Web. 28 July 2018.
    www.youtube.com/watch?v=cMuBlhx8oRI&feature=youtu.be
    b. Ask facilitative questions:
        i. What are some of the differences between **monoculture** and **polyculture** farming?
        ii. Which farming **system** do you think would be better to:
            1. Grow a lot of wheat to make sourdough bread for all of Silicon Valley? (**monoculture**)
            2. Grow a lot of different food in a small space? (**polyculture**)
            3. What if a neighborhood wanted to turn a lot into a garden, which **system** would you recommend and why? (Answers may vary.)

4. Introduce the engineering challenge scenario that students will be working to solve.

The city of San Jose, California wants to make healthy food more accessible to everyone and they are working to strategically place urban food forests around the city. However, they are going to need tools and people to train community gardeners in how to use those tools to collect food so it doesn't go to waste. Your team of engineers has been asked to design tools for getting large fruit from the top branches of the trees without dropping and bruising it.

B. Engineering Challenge (40 Minutes)

1. Think about the **components** of the farming tools we looked at as you consider how to combine materials to make a tool that can help us pick fruit off of the highest branches. We want to design something that won't drop our fruit and bruise it.
    a. *Why would we care about the fruit bruising? (Possible answers include: it might get mushy, it will rot sooner, it won't taste as good in a couple of days.)*
    b. *What kinds of **components** might be helpful to reach and pick the fruit? (Possible answers include: something long and sturdy to reach up, something that can grip, something with finger-like shapes to grasp and pull the fruit off of the tree)*

2. Introduce the engineering design challenge.

Design Problem: Design a tool to harvest fruit from high on a tree without dropping it on the ground.
Criteria (Design Requirements/Desired Features): • Fruit must be picked by the device. • All team members must contribute to the design and building of the device. • Fruit must be delivered to designated zone.
Constraints (Design Limitations): • Dropped fruit is considered damaged and cannot be placed into the designated zone. • Schedule: You have 20 minutes to create a device. • When using the device, do not touch the fruit or tree with your hands or body. • Budget: Use only the provided materials to create your tool.
Testing: • See Set-up and Prep section for information on a possible way to construct a test rig. • Encourage students to test frequently during their build time. • Remind students that they can test their device on the rig for 60 second durations.

3. Prepare students for beginning the **prototyping** phase of the design challenge. (For tips on facilitating prototyping and data collection, see Tech Tip: Prototyping and Tech Tip: Data Collection.)
    a. Hand out the Data Collection sheet (see Appendix D: Handouts - Data Collection).
    b. Explain how students can identify and record design **failure points** on the handout.
    c. (For example, maybe a device keeps dropping the fruit, so it needs a collection component.)
    d. Consider assigning teams and team roles or jobs.

4. Have teams build and test their prototypes for 20 minutes. Ask students facilitative questions as they build:
    a. *What **components** are working well in your device?*
    b. *How do you know what isn't working in your **prototype**?*
    c. *Does your device have any **failure points?** What are they?*

5. Give teams five minutes at the end of build time to:
    a. Record all of their data on the data collection sheet.
    b. Prepare to discuss what they learned with the class.

6. Gather teams together at the test rig so teams get to observe each other's devices. For suggestions on how to structure this discussion and facilitative questions, see Tech Tip: Sharing Solutions.
    a. Consider recording the final share out data as a class for reference during the second design challenge in Part D.

7. Lead a class reflection on what was learned during the building, testing, and share out.
    a. *Which **components** are essential for this tool?*
    b. *What evidence do we have to support this?*
    c. *Were there any consistent **failure points** among our devices? What might we do to iterate on these?*

C. Content Learning (60 Minutes)

1. Introduce the concept of **systems**. Lead the class in a discussion to assess prior knowledge.
    a. *Where have you heard the word **system**? (Students may suggest game system, solar system, nervous system, etc.)*
    b. *What do you think **system** might mean? (Answers may vary.)*
    c. *In science and engineering, a **system** is a group of related parts that make up a whole and can carry out **functions** its individual parts cannot. The tool you made is a **system** that had at least two **components**, probably one part to help reach the fruit and another part to grab the fruit. .*

2. We call the connected things **components** and we call the way they come together to form a whole **interactions**.
    a. *What might be some examples of **components** in the garden? (Possible answers include: the plants, the parts of an irrigation **system**, the tools we need for gardening.)*
    b. *What might be some examples of **interactions** in the garden? (Possible answers include: the way the plants protect each other from pests, how the roots of one plant affect another plant's roots, the ways the pieces of an irrigation system go together to move water, or how we use the tools to help the garden grow.)*
    c. *What types of plants do we need in a food forest for it to be **permaculture**? What do you remember from the video during the introduction? (Possible answers include: plants of different sizes, plants with roots at different levels, plants that bring in different types of pollinators, etc.).*

3. For the city of San Jose project, we are going to make recommendations for plants in the gardens. You are going to research at your tables with your teammates or by yourself to find possible options. Then you are each going to write recommendations for 3 plants and why they would be good for a permaculture garden here in San Jose.
    a. Provide each student with a Plant Recommendation handout (See Appendix D: Handouts - Plant Recommendation.)
    b. Discuss with students what criteria and constraints they may want to consider as they work on their recommendations. (Different heights of plants, local plants, plants that are edible, plants that do well with less water, native species, etc.)
    c. Provide students with resources for research. Consider getting plant catalogs or use online catalogs
        i. "Products." Edible Landscaping. Web. 8 August 2018. http://ediblelandscaping.com/products/buyPlants.php
        ii. "Plant Catalog." Monrovia: Grow Beautifully. Web. 8 August 2018. https://www.monrovia.com/plant-catalog/
    d. Possible facilitative questions:
        i. *How do plants interact with each other in a **permaculture system?***
        ii. *How does a gardener identify **failure points** in a **permaculture system?***
        iii. *If the city council asked you for evidence as to why they should plant the plants you recommended, what would you tell them?*

4. Have a class share out and discussion about the student recommendations.
    a. Go over the questions on the worksheet.
    b. Use student answers to talk about how gardeners need to plan out the urban food farm to balance the components and their interactions to make a well-functioning system.

D. Iterate Solution (50 Minutes)

1. Restate the engineering design challenge and explain the changes in the next design challenge.

> *The city of San Jose, California wants to make healthy food more accessible to everyone and they are working to strategically place urban food forests around the city. However, they are going to need tools and people to train community gardeners in how to use those tools to collect food so it doesn't go to waste. Your team of engineers has been asked to design tools for getting large fruit from the top branches of the trees without dropping and bruising it.*

   a. Add criteria and constraints either based on teacher choice or incorporating students ideas from their plant recommendations. Possible additional criteria could be:
      i. Picks fruit from up high and down low.
      ii. Picks two different-sized fruits.
      iii. Picks two different fruit shapes.
      iv. Picks fruit that is firm and fruit that is squishy.
   b. Encourage students to incorporate what they learned from:
      i. The first design challenge,
      ii. Observing other team's devices.
      iii. Research on plants for the urban food forest.

Design Problem: Design a system to pick multiple types of produce in the urban food forest.
Criteria (Design Requirements/Desired Features): • Tool must be able to pick more than one type of produce. • All team members must contribute to the design and building of the tool. • Undamaged fruit must be delivered to designated zone. • Specifically record improvements that were made to the working system of your tool.
Constraints (Design Limitations): • Do not drop the fruit on the floor. • When using the tool, do not touch the fruit with your hands/body. • Budget: Use only the provided materials to create your tool. • Schedule: You have 30 minutes to create a device.
Testing: • Pick up as much fruit off the test rig in 60 seconds. • Record how much fruit is saved and how much fruit fell on the ground. • Encourage students to test frequently during their build time. • Remind students that they can test their device on the rig for 60 second durations. • Remind students to record failure points and describe what they changed to improve their design.

2. Give students 30 minutes to build, test, and record their designs.
   a. Give each team a new Data Collection sheet.
   b. Ask students facilitative questions:
      i. How did you use what you have learned to create this prototype?
      ii. What failure points have you identified in your system?
      iii. What is working well in your system?

3. Perform a final test and share out so teams can see each other's work.
   a. Ask teams how their improvements meet the new criteria.
   b. Have students make observations about their design during testing. These types of share outs during

testing will help reinforce vocabulary, design strategies, and engineering concepts.

c. Ask teams questions like:
   i. *What is a **component** of another team's design that you would like to include in your **system** to improve it?*
   ii. *What is a **failure point** in your **system** that you saw another team's design address successfully? Could you use this to improve your system?*
   iii. *What types of other real world farming uses can your device support?*

E. Evaluation (120 Minutes)

1. Review the final assessment project with students. Students will create a final design to be used at multiple urban food farm locations around San Jose. They will need to come up with a way to communicate how to use the tool efficiently on the farm. (See Appendix D: Handouts - Assessment.)
   Students will:
   a. Create a diagram of their device with labeled components and explanation of how these components interact as a system.
   b. Explain the modifications they made to their device to address failure points.
   c. List which types of food on the farm can be harvested with their device.
2. Review the rubric with students at the introduction of the project. (See Appendix D: Handouts - Rubric.)
   a. Go over learning goals and standards with students that connect to the learning.
   b. Emphasize that success is measured by the learning and not in solving the problem/challenge.

3. Consider gathering a panel for student presentations to make the final evaluation feel more real

Appendix A – Vocabulary

The following is the start of a suggested list of words to discuss as your progress through this unit with students. For more in depth information about vocabulary and teaching information, visit Tech Tip: The Language of Engineering.

Term	Student-friendly definition
components	The parts of a system.
failure points	A place where the design or system failed.
function	The intended purpose for a thing.
interactions	How the components of a system work together to achieve a goal.
monoculture farming	The production of a single crop, livestock species or agricultural product.
permaculture	An agriculture system meant to be sustainable and self sufficient.
polyculture farming	The production of multiple crops at the same farm.
prototype	The model(s) that you build to test before you get to your final solution.
system	A set of connected things that come together to form a whole.

Appendix B - Resources

Farming

Types of Farming Tools	Tee, Oharra. "Farm Tools and Implement." LinkedIn SlideShare, 23 November 2014. Web. 8 August 2018. www.slideshare.net/oharratee/farm-tools-and-implement
Possible Field Trip in San Jose, CA	"Prusch Farm Park Foundation." Prusch Farm Park Foundation. Web. 8 August 2018. www.pruschfarmpark.org
Background on Urban Food Forests	Ignaczak, Nina Misuraca. "20 Urban Food Forests from Around the World." Shareable, www.shareable.net/blog/20-urban-food-forests-from-around-the-world.
Polyculture vs. Monoculture	"The Advantages of Polyculture vs Monoculture." Weather Underground. Web. 28 July 2018 www.wunderground.com/blog/organicfarmingblog/the-advantages-of-polyculture-vs-monoculture.html

Appendix C - Lesson Handouts

Data Collection

Draw a diagram of your **device.** Include labels for:

a. Failure points observed during testing.
b. Each **component** and its **functions**,

Date:	Prototype #:	Name:

Quantitative Data: *number of "fruits" collected safely, number of "fruits" dropped*

Test #1	Test #2	Test #3	Test #4
Safe: Dropped:	Safe: Dropped:	Safe: Dropped:	Safe: Dropped:

Strengths of the design are:

The **failure points** of this **prototype** are:

To improve on our **prototype**, we can iterate our device to make it successful by:

Plant Recommendation:

Student Name:________________________________

What is a permaculture system?

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The city of San Jose is wanting to make urban food forests. This is your chance to make three recommendations for the design.

Recommendation #1:	**Recommendation #2:**	**Recommendation #3:**
Why?	**Why?**	**Why?**
What are the benefits for the garden or community (produces something edible, provides shade, etc.)?	**What are the benefits for the garden or community?**	**What are the benefits for the garden or community?**
Does this plant have any needs (sunlight, space, watering, etc.)?	**Does this plant have any needs?**	**Does this plant have any needs?**

Explain how these three plants will interact in the same garden to form a permaculture system?

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Assessment

Your task is to develop a presentation to explain how your device works to volunteer gardeners at the new San Jose urban food farms.

Individual Written Component Guidelines:

- Explain at least 2 modifications your team made to the device to address **failure points**. Include evidence from your data collection to support why you made these modifications.
  - Modification 1 (with data collection evidence):
  - Modification 2 (with data collection evidence):
- Create a diagram of your team's device that includes:
  - 3 labeled **components**.
  - 2 foods that can be harvested and by which end of your device.
- Explain how the **components** in your diagram **interact** as a **system**.

Group Presentation Guidelines:

Now team it is time to present your findings to volunteers at the farm:

- Each team member presents some aspect of the individual written **component**.
- All content from the individual written **component** must be included in the group presentation.
- Team demonstrates how to use the device.

RUBRIC: Save the Fruit! Prevent Food Waste!

	Below Standard	Approaching Standard	Meeting Standard	Above Standard
NGSS Engineering Design (PE) 3-5 ETS 1-3 *Plan and carry out fair tests in which variables are controlled and **failure points are considered to identify aspects of a model or prototype that can be improved.***	• Student provides an answer but it is unclear what the modification or failure points were in the prototype. *Areas that individual students may need one-on-one support with:* • Manageing time efficiently in order to test device during build time. • Documenting test trials in order to ildentify failure points within a design. • Brainstorming ideas for improvement of a design.	• Student's individual assessment includes 1 identified modification **OR** discusses a failure point.	• Student's Individual assessment includes 2 identified modifications to address failure points.	*Areas where students may exceed:* • Student's individual assessment includes 3 or more modifications and failure points. *Ideas for next steps for growth:* • Team modifies tool to harvest a different type of produce. • Team makes one device that can be used to harvest 3 differing types of produce.
NGSS Developing and Using Models (SEP 2, 3-5). ***Collaboratively** develop and/or **revise a model based on evidence** that shows the relationships among variables for frequent and regular occurring events.*	• Student provides data that does not support their design choices. *Areas that individual students may need one-on-one support with:* • Persevering and not giving up too early. • Identify data to support a decision. • Time management. • Team work.	• Student's individual assessment provides 1 piece of data from their data collection sheet to support **one** modification. • Student stands with team, but does not present any component.	• Student's individual assessment provides 1 piece of data from their data collection sheet to support **each** modification. • Student presents some aspect of the individual assessment in the group presentation.	*Areas where students may exceed:* • Student finds research to further support their modification choices. *Ideas for next steps for growth:* • Test their device in other environments. • Develop additional criteria and constraints that they test their device on
NGSS Systems and Systems Models (CCC 4, 3-5) *Students understand that a system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. **They can also describe a system in terms of its components and their interactions.***	• Student's individual assessment includes a diagram. *Areas that individual students may need one-on-one support with:* • Identifying components of their systems. • Identifying how components work together to create a whole system. • Defining a system.	• Student's individual assessment includes a labelled diagram with: – 2 labelled components. – 1 foods that can be picked with the team's device. – Explanation of how the components of the device interact as a system is inaccurate or unclear.	• Student's individual assessment includes a labelled diagram with: – 3 labelled components. – 2 foods that can be picked with the team's device. – A clear, accurate explanation of how at least 2 components in their device interact as a system.	Areas where students may exceed: • Student's individual assessment includes a labelled diagram with: – 4 or more labelled components. – 3 or more food types that can be picked with the team's device. – A detailed explanation of how 3 or more components interact as a system. *Ideas for next steps for growth:* • Student draws a model of their ideal urban food farm. • Student draws out additional system components for the farm like irrigation.