EngrTEAMS

EngrTEAMS: Engineering to Transform the Education of Analysis, Measurement, and Science in a Team-Based Targeted Mathematics-Science Partnership

Greenhouse

Grades 4-6

University of Minnesota
STEM Education Center
NSF
INSPIRE Research Institute for Pre-College Engineering
Purdue University

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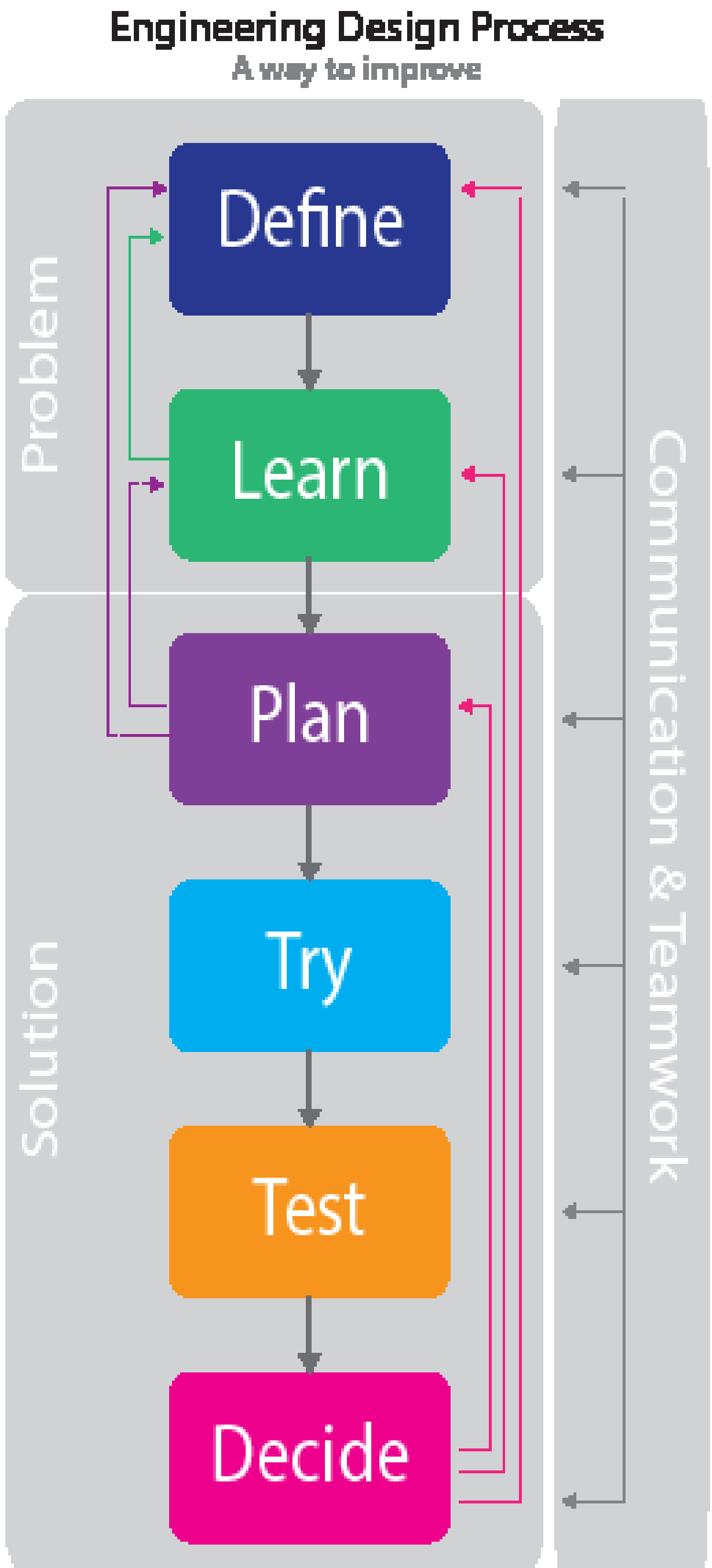
About EngrTEAMS

Purpose
The project is designed to help 200 teachers develop engineering design-based curricular units for each of the major science topic areas within the Minnesota State Academic Science Standards, as well as data analysis and measurement standards for grades 4-8.

With a focus on vertical alignment and transition from upper elementary to middle-level, this project will impact at least 15,000 students over the life of the grant.

To learn more about the project and find additional curricular units go to www.engrteams.org.

Overview


Engineering Design Process
A way to improve
Problem
Solution
Define
Learn
Plan
Try
Test
Decide
Communication & Teamwork

Overview

DEFINE THE PROBLEM

- Who is the client? What does the client need? Why does she or he need it? Who are the end-users?
- Why is the problem important to solve? What are the criteria (requirements) of the solution? What are the constraints (limits)?
- Problem Scoping: WHO needs WHAT because WHY

LEARN ABOUT THE PROBLEM

- What kind of background knowledge is needed to solve the problem? What science/mathematics knowledge will be needed? What materials will be needed?
- What has already been done to solve the problem? What products fill a similar need?
- How should we measure improvement?

PLAN A SOLUTION

- Continue to specify the criteria and constraints
- Idea generation
- Develop multiple possible solution paths
- Consider trade-offs and relative constraints
- Choose a solution to try
- Develop plans (blueprints, schematics, cost sheets, storyboards, notebook pages)

TRY A SOLUTION

- Put the plan into action
- Consider risk and how to optimize work
- Use criteria, constraints, and trade-offs from problem/plan to build a prototype (a testable representation of a solution), model, or product

TEST A SOLUTION

- Consider testable questions or hypotheses
- Develop experiments or rubrics to know if the solution is meeting the stated criteria, constraints, and needs
- Collect and analyze data

DECIDE WHETHER SOLUTION IS GOOD ENOUGH

- Are users able to use the design to help with the problem?
- Does your design meet the criteria and stay within the constraints?
- How could your design be improved based on your test results and feedback from client/user?
- Iterative nature of design: Consider always which step should be next!

COMMUNICATION & TEAMWORK

- Good oral and written communication and teamwork are needed throughout the entire design process.
- The client should be able to create/follow the solution without ever speaking to you. Include claims and use evidence to support what you believe is true about your solution so that the client knows why they should use it.

Overview

Grade Levels: 4-6

Approximate Time Needed to Complete Unit: Twelve 50-minute class periods

Unit Summary

St. Paul, Minnesota has a long tradition of selling goods at the farmers market. It was St. Paul's first public market. While fresh produce is only available during the summer season, dairy products, flour, cakes and candies could be purchased year-round. Many families of students in schools in Minnesota grow and sell fresh produce at the market. However, the growing season for produce (tomatoes) in Minnesota is very limited due to the climate. Students will discover that to extend the growing season for tomatoes they will need to design and construct a model greenhouse that will maintain an optimal temperature closest to 24°C and maintain a temperature between 18°C and 35°C.

Science Connections	Technology & Engineering Connections	Mathematics Connections
• Plant parts and needs of plants • Optimal habitat for a living organism	• Engineering design process, criteria and constraints • Using appropriate tools • Using evidence and make systematic observations	• Data collection and analysis • Surface area • Cost analysis • Line graphs

Unit Standards

Next Generation Science Standards

- LS1. B: Growth and development of organisms
- MS-LS1-4: Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features for reproduction.
- LS2A: Independent relationships in ecosystems
- MS-LS2-1: Growth of organisms and population increases are limited by access to resources.
- 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-ETS1-4: 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.

Common Core State Standards - Mathematics

- 5GA.1: Use a pair of perpendicular number lines, called axes, to define a coordinate system, with the intersection of the lines (the origin) arranged to coincide with the 0 on each line and a given point in the plane located by using an ordered pair of numbers, called its coordinates.
- 5GA.2: Represent real world and mathematical problems by graphing points in the first quadrant of the coordinate plane, and interpret coordinate values of points in the context of the situation.

Overview

Unit Assessment Summary

- Throughout this unit, each student will maintain an Engineering Notebook to document their engineering design processes. In this, students will make observations, collect data, and plan for their design. Part of the Engineering Notebook will include answering specific questions related to that day's activities. You may choose to post the questions in your overhead/PowerPoint slides, or give the students printed versions to tape into their Notebooks. Students will also use their Notebooks as a reference – a place to maintain the information they are learning through design. Additionally, students will reflect on their work throughout the design process. This is important for modeling what real-life engineers do. **Collect the Engineering Notebooks at the end of each class.** You will use the Notebooks to assess student learning and their design process. Read the Notebooks and provide feedback to students. You are encouraged to assign points for responses in the engineering notebooks.
- The notebook pages are often set up as handouts in each lesson. If you prefer to use notebooks without having students paste copied pages in them, there is an appendix at the end of this unit that includes notebook prompts and how to have students title each entry.
- There is a pre-post content assessment in this unit.
- The final summative piece of this unit requires students to provide a process and a presentation for their client.

Overview

Lesson 1: Introduction to the Engineering Design Challenge

This session will begin with a discussion about the St. Paul Farmers Market and what goods may be sold at the Farmers Market. Students will be asked if they know why only certain produce is sold during certain parts of the year. Students will then be given the problem: How could we extend the growing season for tomatoes? Students will begin by examining some plants and brainstorming their needs for survival.

Lesson 2: Plant Parts

Students will examine tomato plants and they will then sketch a tomato plant and label the parts. Students will learn that different structure of planst serve various functions of growth, survival, and reproduction.

Lesson 3: Testing Materials

Students will test materials. Students will record data and make claims based on their data. They will then begin to examine how they could utilize this phenomenon to extend the growing season for tomatoes in Minnesota.

Lesson 4: Design and Cost Analysis of Greenhouse

Students will design and do cost analysis. Students will be given a set of materials to examine as they design. Students will sketch their design and come up with a list of materials. They will be given the scoring rubric and the list of material costs. The drawings will need to be made to scale. Students must submit plans to teacher before approval to build.

Lesson 5: Construct and Test Greenhouses

Students will construct greenhouses based on their plan. They will then test their designs to examine how they maintain the optimal temperature in a 10-minute period while they are exposed to light and then continue to monitor after 10 minutes after light source is off. Students will graph this data and examine how well it meets the needs of the challenge. Students will share designs and the effectiveness.

Lesson 6: Redesign and Cost Analysis of Greenhouse

Students will use the prior knowledge that they obtained during lessons 4 and 5 to work on their redesign. They should examine the effectiveness of their previous greenhouse. Students will then work on their redesign and come up with a new design that will be more effective based on the challenge. Students can also examine how they could increase their point total. All redesigns must be approved by the teacher.

Lesson 7: Build and Test Redesign

Students will use their redesign to gather materials and construct their improved model. They will then test their improved designs to examine how they maintain the optimal temperature in a 10-minute period while they are exposed to light and then continue to monitor after 10 minutes after light source is off. Students will graph this data and examine how well it meets the needs of the challenge. Students will share designs and the effectiveness.

Lesson 8: Communication

Students will work in teams to communicate with client the challenge, a claim on why their design is successful, evidence to support the claim, an explanation for why their design should be selected, and addressing any weaknesses in their design. Students will write a report to their client and make presentations to the class.

Overview

Lesson	Time Needed	Objectives The student will be able to:
1: Introduction to the Engineering Design Challenge	Two 50-minute class periods	• Define the problem, criteria, and constraints • Review plant needs for survival and recognize the limitations of the growing season in Minnesota.
2. Plant Parts	One 50-minute class period	• Define the problem, criteria and constraints and identify learning required to solve the problem. • Review plant needs for survival and recognize the limitations of the growing season in Minnesota.
3: Testing Materials	One 50-minute class period	• Become familiar with heat radiation, transmittance and absorption. • Utilize these concepts as they become familiar with the working of a greenhouse.
4: Design and Cost Analysis of Greenhouse	Two 50-minute class periods	• Utilize their knowledge from the previous lesson to design a greenhouse that will extend the growing season for tomatoes in Minnesota. • Determine the surface area and materials costs.
5: Construct and Test Greenhouses	Two 50-minute class periods	• Construct and test their model greenhouses based on their design from yesterday. • Collect data to determine the effectiveness of their greenhouse.
6: Redesign and Cost Analysis of Greenhouse	One 50-minute class period	• Utilize their knowledge from previous lesson to redesign a greenhouse that will extend the growing season for tomatoes in MN. • Determine the surface area and materials cost.

** required materials not included in the kit*

Overview

Materials	Duplication Masters
• **Per classroom:** Tomato Plant for class* • **Per group:** none • **Per student:** 1 Engineering Notebook*, 1 Engineering design slider*	• 1.a. Client letter • 1.b. Problem Scoping Prompts • 1.c. Growing Tomatoes
• **Per classroom:** Tomato plant for class, 8 Tomatoes purchased from a grocery store, Knife (for teacher), Chart Paper, Markers • **Per group:** 1 Hand lens, Several markers of different colors*, • **Per student**: 1 Engineering Notebook*	• 2.a. Word bank **EDUCATOR RESOURCES** • 2.b. Diagram of a Tomato Plant
• **Per classroom:** 6 6 in. x 6 in. Cardboard boxes, 6 Thermometer, 6-60 Watt bulbs, 6 8 ½ in. Clamp lights, 5 Test materials- plastic wrap, bubble wrap, transparency sheet, page protector, plastic folder • **Per group:** 1 6 in. x 6 in. Cardboard box, 1 Thermometer, 1-60 Watt bulb, 1 8 ½ in. clamp light • **Per student:** 1 Engineering Notebook*	• 3.a. Recording sheet **EDUCATOR RESOURCES** • 3.b. Set up for Data Collection
• **Per classroom:** 8 Calculators, 8 Metric rulers, 8 15-Centimeter grid transparencies, Transparency markers • **Per group:** 1 calculator, 1 Metric ruler, 1 15-Centimeter grid transparencies, Transparency markers • **Per student:** 1 Engineering Notebook*	• 4.a. Cost List • 4.b. Scoring Rubric • 4.c. Engineering Design Sheet • 4.d. Evidence-Based Reasoning Sheet **EDUCATOR RESOURCES** • 4.d. Evidence-Based Reasoning Poster with Explanations
• **Per classroom:** 8 Thermometers, 8 8 ½ in. Clamp lights, 8-60 Watt bulbs, 8 Stop watch, 8 Clear tape, 50 Pack transparencies, Sheet protector (box of 50), Stretch wrap, Bubble wrap, Plastic folder, White felt, Aluminum foil, Box cutter (for the teacher), 8 Scissors, 8 Shoe boxes, 10-15 Tomato seeds, Potting soil, 8 Plastic cup to plant tomato seeds • **Per group:** 1 Thermometer, 1 8 ½ in. Clamp light, 1-60 Watt bulb, 1 Stop watch, 1 Clear tape, 50 Pack transparencies, Sheet protector (box of 50), Stretch wrap, Bubble wrap, Plastic folder, White felt, Aluminum foil, Box cutter (for the teacher), 1 Scissor, 1 Shoe box, 3-4 Tomato seeds, Potting soil, 1 Plastic cup to plant tomato seeds • **Per student:** 1 Engineering Notebook*	• 5.b. Greenhouse Testing Recording Sheet • 5.d. Growth and Development of Tomato Plants **EDUCATOR RESOURCES** • 5.a. Teacher Observation Protocol: Try Lesson • 5.c. Teacher Observation Protocol: Test Lesson
• **Per classroom:** 8 Calculators, 8 Metric rulers, 8 15 Centimeter grid transparencies, Transparency markers • **Per group:** 1 Calculator, 1 Metric ruler, 1 15 Centimeter grid transparencies, Transparency markers • **Per student:** 1 Engineering Notebook*	• 6.a. Design Sheet • 6.b. Materials cost list • 6.c. Scoring Rubric • 6.d. Evidence based reasoning sheet

Overview

Lesson	Time Needed	**Objectives** The student will be able to:
7: Build and Test Redesign	Two 50-minute class periods	• Construct and test their model greenhouses based on their redesign from yesterday. Students collect data to determine the effectiveness of their redesigned greenhouse.
8: Communication	One 50-minute class	• Work in groups to write a report to the client and share out.

** required materials not included in the kit*

Overview

Materials	Duplication Masters
• **Per classroom:** 8 Thermometers, 8 8 ½ in. Clamp lights, 8-150 Watt bulbs, 8 Stop watches, 8 Clear tape, 50 Pack transparencies, Sheet protectors (box of 50), Stretch wrap, Bubble wrap, Plastic folder, White felt, Aluminum foil • **Per group:** 1 Thermometer, 1 8 ½ in. clamp light, 1-150 Watt bulb, 1 Stop watch, 1 Clear tape, 50 pack transparencies, Sheet protector (box of 50), Stretch wrap, Bubble wrap, Plastic folder, White felt, Aluminum foil, Box cutter (for the teacher), 1 Scissor, 1 Shoe box • **Per student:** 1 Engineering Notebook*	• 7.b. Greenhouse Testing Recording Sheet **EDUCATOR RESOURCES** • 7.a. Teacher Observation Protocol: Redesign Try • 7.c. Teacher Observation Protocol: Redesign Test
• **Per classroom:** none • **Per group:** Data from previous lessons, Laptop or iPad to type memo* (not required), Poster paper* (not required) • **Per student:** Engineering notebooks*	• 8.a. Evidence-Based Reasoning - Solution Graphic • 8.b. Final Communication to the Client Rubric • 8.c. Science Assessment • 8.d. Engineering Notebook Reflection Questions

Overview: Master Material List

	Material	Lessons Where Material is Used
Per classroom	1 Tomato plant for class	1, 2
	6 6 in. x 6 in. Cardboard boxes	3
	8 60 Watt bulbs	3, 5, 7
	6 Thermometers	3, 5, 7
	6 8 ½ in. Clamp lights	3, 5, 7
	8 Calculators	4, 5, 6
	8 Metric rulers	4, 5, 6
	8 15 Centimeter grid transparencies	4, 6
	8 Transparency markers	4, 6
	Stop watches	5, 7
	8 Clear tape	5, 7
	1 50 Pack of transparencies	5, 7
	Sheet protector (box of 50)	3, 5, 7
	Saran wrap	3, 5, 7
	Bubble wrap	3, 5, 7
	8 Plastic folders	3, 5, 7
	White felt	3, 5, 7
	Aluminum foil	3, 5, 7
	Box cutter (for teacher)	3, 5, 7
	8 scissors	5, 7
	16 Shoe boxes	5, 7
	8 Tomatoes purchased from a grocery store	2
	Knife (for teacher)	2
	10-15 Tomato seeds	5
	Potting soil (enough to fill 8 cups)	5
	8 Hand lenses	2
	8 Plastic cups to plant tomato seeds	5
Per group (assuming 3 students per group)	1 6 in. x 6 in. Cardboard box	3
	1 60 Watt bulb	3, 5, 7
	1 Thermometer	3, 5, 7
	1 8 ½ in. Clamp light	3, 5, 7
	1 Calculator	4, 2, 6
	1 Metric ruler	3, 4, 6
	1 15 Centimeter grid transparency	3, 6
	1 Transparency marker	3, 6
	1 Stop watch	3, 5, 7

Overview: Master Material List

	Material	Lessons Where Material is Used
	1 Clear tape	3, 5, 7
	1 50 Pack of transparencies	3, 5, 7
	Sheet protector (box of 50)	3, 5, 7
	Stretch wrap	3, 5, 7
	Bubble wrap	3, 5, 7
	1 Plastic folder	3, 5, 7
	White felt	5, 7
	Aluminum foil	5, 7
	1 scissor	5, 7
	16 Shoe boxes	5, 7
	1 Tomato purchased from a grocery store	2
	3-4 Tomato seeds	2, 5
	Potting soil (enough to fill cup)	5
	1 Hand lens	2
	1 Plastic cup to plant tomato seeds	5
Per student	1 Pen*	1, 2, 3, 4, 5, 6, 7, 8
	1 Notebook*	1, 2, 3, 4, 5, 6, 7, 8
	1 Client letter*	1
	1 Copy of recording sheet*	2
	1 Copy of lesson worksheet	3, 4, 5, 7

* required materials not included in the kit

LESSON 1

Introduction to Engineering Design Challenge

Lesson Objectives

The student will be able to:

- Define the problem, criteria and constraints and identify learning required to solve the problem.
- Review plant needs for survival and recognize the limitations of the growing season in Minnesota.

Time Required

Two 50-minute class periods

Materials

- **Per classroom:** Tomato Plant for class*
- **Per group:** none
- **Per student:** 1 Engineering Notebook, 1 Copy of lesson worksheets (1.a, 1.b, 1.c.), 1 Engineering design slider*

Standards Addressed

- Next Generation Science Standards: MS-LS1-4, MS-LS2-1, MS-ETS1-1

Key Terms

problem scoping, client, criteria, constraint, design, engineer, plant growth

Lesson Summary

This session will begin with a discussion about the St. Paul Farmers Market and what goods may be sold at the Farmers Market. Students will be asked if they know why only certain produce is sold during certain parts of the year. Students will then be given the problem: *How could we extend the growing season for tomatoes?* Students will begin by examining some plants and brainstorming their needs for survival (food, water, air). Students will then read an article that relates to tomato plant growth and determine what would be needed to extend the growing season for tomatoes.

Background

Teacher Background

- Become familiar with the engineering design process.

Before the Activity

Preparation for the unit:

- Administer the pre and post assessments (science test, engineering test, and survey)
- Have students start germinating tomato seeds. Give each group a plastic cup filled with potting soil. Ask students to make shallow furrows with a pencil about 1/4 in deep. Have students sow seeds by dropping them along the bottom of the furrows 1/2 in apart. Ask students gently cover each furrow with soil and water. Put plastic cups in a warm place and water each day (1-2 tablespoon). Seedlings need about 7 days to germinate.

Preparation for the lesson:

- Get materials ready, including the video link of the Farmers' Market. You may want to find and print photos of the Farmers' Market.
- Copy student documents and engineering design process sliders.
- Bring several different plants including a tomato plant to class for students to make observations and brainstorm ideas about needs of plants.

Classroom Instruction

Introduction

1. **Introduce the concept.** Ask students if anyone has been to the Farmers' Market. Lead a discussion about what can be found at the Farmers' Market and what items are typically sold there. If you have photos of the Farmers' Market, show them and discuss who some of the vendors may be. Show video http://www.stpaulfarmersmarket.com/video of a vendor at the St. Paul Farmers' Market. **Ask:** *Do you think fresh produce can be sold at the Farmers' Market all year? Why or why not?*

Activity

1. **Introduce students to the greenhouse unit and engineering. Say:** *We are going to be working as engineers over the next few days.* Have students answer the following two questions in their Engineering Notebook.
   - *What do engineers do?*
   - *How do engineers solve problems?*

   Say: *Turn and talk with your partner about what engineers do.* Have students share out their definition and define engineering as a class.

Introduction to Engineering Design Challenge

LESSON 1

Engineers are people who use science, mathematics, and creativity to solve probelmes to help people. Typically their solutions is a new and improved technology or a process.

2. **Introduce the problem.** Pass out the Memorandum from the St. Paul Farmers' Market, *1.a. Client Letter*. Read it aloud with the students and review vocabulary design, challenge, and constraints.
3. **Identify client's needs.** Ask students to identify the client's needs with their team.
4. **Decide on questions for the client.** Tell students that you have talked to the client earlier and may know some additional information about the challenge. Have them respond to the following prompt in their Engineering Notebook:
   - *What questions do you want to ask to the client?*

   Try to answer the questions students have for the client as much as possible. Then answer students' questions about the design challenge.
5. **Define the problem.** Ask students to define the problem by completing the *1.b.Problem Scoping Prompts* first individually and then with their team. Have groups share their responses with the class. Write the engineering problem as a class.
6. **Introduce the engineering design process and the slider.** Ask students to determine where they are on the problem. Explain to students what they are going to need to do to address this problem as engineers.
7. **Read about growing tomatoes.** Have students read the article about tomatoes (*1.c. Growing Tomatoes*). Ask them share out what they have learned about growing tomatoes.

Closure

1. **Create a list of what needs to be learned.** Ask students what they still need to learn to solve the problem. **Ask:** *Think about the problem of greenhouse design. In terms of designing a greenhouse to extend the growing season of tomatoes, what do you need to learn in order to create a successful design?*

Assessments

Pre-Activity Assessment

At the beginning of the lesson, the students will be asked to name any parts and functions of the plant that they may be aware of through prior knowledge. They will also be asked if they are aware of the basic needs of plants.

In Engineering Notebook, students are to answer the following question:

1. How do engineers solve problems?

Activity Embedded Assessment

Pair and share growing solutions: Ask each pair to share their possible solution for extending the growing season for tomatoes.

In Engineering Notebook, there are questions associated with each lesson.

Post-Activity Assessment

Ask students which step of the engineering design process students are in currently.

DUPLICATION MASTERS

- 1.a. Client Letter
- 1.b. Problem Scoping Prompts
- 1.c. Growing Tomatoes

EDUCATOR RESOURCES

- none

LESSON 1

Name_________________________________ Date____________ Period _____

1.a. Client Letter

To: Life Science Class

From: St. Paul Farmers' Market Group

RE: Request for Proposal, Greenhouse Design

Attention! The St. Paul Farmers' market needs your help. Everybody who comes to the market loves to buy Minnesota grown tomatoes. Unfortunately, they usually are not available until July. We would like to make them available much earlier, possibly at the beginning of June.

Our vendors (growers) would like to start their tomato plants earlier to help meet this demand. Our climate only allows us to start planting tomato plants outside after June 1st. Tomato plants will die if it is too cold or if it is too warm. Our big problem is the cold temperatures in April and May.

We would like you to please consider designing a model greenhouse for our vendors that would help us extend our season for growing tomatoes. We will need to consider temperature and costs. In order to achieve this design task you will need to go through the engineering design process. You will build a model greenhouse and test how your tomato plant grows in it over several weeks. You will communicate your design by writing a report to us. The report will include sketches of your design, observations, results from your experiments, and your budget.

Thank you for your consideration!

Sincerely,

St. Paul Farmers' Market Group

LESSON 1

Name________________________________ Date__________ Period _____

1.b. Problem Scoping Prompts

First, **on your own**, answer each of the following questions beside the "My Response" space. Then, in your teams, each person is to share their response and discuss. In the space, "Team Response" **write your revised answer to the question**, based on discussion with your team. You may use a different color writing utensil to distinguish your answer and how it changed after talking with teammates.

1. Who is the client?
My response:

Team response:

2. What is the client's problem that needs a solution?
My response:

Team response:

3. Why is the problem important to solve?
My response:

Team response:

4. Who are the end-users?
My response:

Team response:

Name________________________________ Date___________ Period _____

1.b. Problem Scoping Prompts

5. **What will make a solution effective (criteria)?**
   My response:

   Team response:

6. **What will limit how you can solve the problem (constraints)?**
   My response:

   Team response:

7. **Think about the problem of greenhouse design. In terms of designing a greenhouse to extend the growing season of tomatoes, what do you need to learn in order to create a successful design?**
   My response:

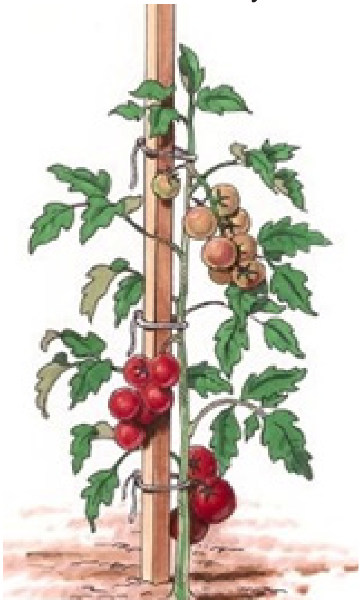
   Team response:

LESSON 1

Name________________________________ Date__________ Period _____

1.c. Growing Tomatoes

There is nothing like a fresh, sun-warmed tomato, so growing tomatoes is on everyone's list. There are many kinds of tomatoes to consider, from beefsteak to cherry to heirloom varieties. There are also petite types bred specifically for hanging baskets. Tall and rangy cherry types can be trained up a trellis or over an arch.



Tomatoes grow best when the daytime temperature is between 65 and 85 degrees Fahrenheit. They stop growing above 95 degrees Fahrenheit. If nighttime temperatures are above 85 degrees Fahrenheit, the fruit will not turn red. Tomatoes need full sun and warm, well-drained soil. This is an important consideration when tomatoes are placed in a greemhouse.

Start tomatoes either by seed planted in the garden on the average date of last frost or from transplants set in the garden about a week after the average date of last frost. If you use transplants, either purchase them from a reputable nursery or garden center or start your own indoors six to eight weeks before the planting date. Plant transplants 18 to 36 inches apart, depending on whether you will stake or cage the plants or let them sprawl.

Set transplants out on a cloudy day or in the late afternoon. If the sun is very hot, protect the plants with a temporary shade of newspapers. Disturb the roots of transplants as little as possible. If the stems are leggy or crooked, set the plants deeply or in a trench. Side roots will develop along the stem, and the top will turn in the right direction.

Harvesting Tomatoes
The time from planting to harvest is 50 to 180 days from transplants, depending on the variety. The color when ripe depends on the variety. Ripe tomatoes should feel firm, neither squashy nor too hard.

Tomato Growing Tips
These tips will help you grow sweet, delicious tomatoes:

- Prune tomato plants to direct maximum energy into tomato production. Choose your pruning plan based on what you want from your tomatoes. For larger and earlier (but fewer) tomatoes, remove any shoots that emerge on or beside the main stem, and tie the stem to a stake. For more tomatoes later, let plants bush out and support them in tomato cages. Pinch off any flowers that open before July 4.
- Choose tomatoes according to the way you prefer to harvest. Some tomatoes (such as Celebrity) tend to stay compact and produce most of their tomatoes at about the same time. This is convenient for freezing, canning, and sauce making. Other tomatoes (such as Big Beef) keep growing and developing new tomatoes as they go. They produce a greater yield but spread it over a longer harvest period.
- Stake your tomato cages so a bumper crop or a crop that has a very large harvets, won't pull them over. Work a tall stake through the wire mesh near the perimeter of the cage, and stab or pound it to 8 inches deep in the ground. This will anchor the cage (and the plant inside) firmly despite the pull of strong winds and branch full of ripening tomatoes.

Source: http://home.howstuffworks.com/tomatoes1.htm

LESSON

2 Plant Parts

Lesson Objectives
The student will be able to:
- Understand the plant parts and structure.

Time Required
One 50-minute class period

Materials
- **Per classroom:** Tomato plant for class, 8 Tomatoes purchased from a grocery store, Knife (for teacher), Chart Paper, Markers, 10-15 Tomato seeds, Potting soil, 1 display copy of lesson worksheet (2.b.)
- **Per group:** 1 Hand lens, 1 Thermometer (scale 0-50°), 1 Metric ruler, Several markers of different colors*, 1 Plastic cup to plant tomato seeds
- **Per student**: 1 Engineering Notebook*, 1 Copy of lesson worksheet (2.a.)

Standards Addressed
- Next Generation Science Standards: MS-LS1-4, MS-LS2-1

Key Terms
stem, root, fruit, leaf

Lesson Summary
In this lesson, students will explore plant parts and undertsand how their greenhouse will affect plant growth. They will make observations and dissect flower of a tomato plant.

Background
Teacher Background
- Students will grow tomatoes in their greenhouses. However, growing tomatoes from seeds would take 4-6 weeks. Due to time constraints we would suggest that students start germinating seeds ahead of time. Ask students plant their seeds about 7-10 days before you start the unit. They will place the seedlings in their greenhouses and let them grow about 2 weeks. Students will make observations over the 2-3 weeks. They can make observations 2-3 times a week and record their observations until the plants grow about 10-15 cm tall.
- How to plant tomato seeds: Fill the plastic cups to within ½" of the top. Place 2-3 seeds into each container and cover the seeds about ¼" of soil. Water the seeds. Seeds germinate best at room temperature and they do not need light. Check the cups daily and as soon as you see sprouts place them under grow light. Seedlings grow best at room temperature.
- Use grow light to speed up grow process of tomatoe plants in the greenhouse. Give a grow light to each group.
- Make sure students will water their plants at the same time and all use the same amount of water (3 tablespoons).
- We also suggest you to grow a tomato plant and place it in dark so that it will be a control. This would help students to understand the influence of light on plant growth.

Before the Activity
Prepare the materials for students.

Classroom Instruction
Introduction
1. **Tie to the engineering challenge.** Revisit the engineering design process and our design challenge. We said that engineering design process is a set of steps used by engineers to help them solve problems. **Ask.** *Who can remember what the problem we are trying to solve again?* (To design a greenhouse to increase the growing season of tomatoes in MN.) **Ask.** *What additional things we need to know to find if our designs are successful?* (Plant growth and plant structures).

Activity
1. **Assess prior knowledge about tomatoes and tomato plants.** Review the article from the first lesson. Ask students what the structural components of tomato plants are. Show students a tomato, a tomato plant, and any other plants that you may have readily available.
2. **Group practice drawing and labeling plants.** Put students in pairs and give each group a set of markers and poster paper. Have them draw a tomato plant and include as many parts as possible including the roots. Have students also label functions of any parts they may know. Also have

students make observations using a hand lens to view an intact flower. Students will then dissect a flower and draw a sketch of their flower. Also pass out the *2.a.Word Bank* sheet that students may use as a guide in labeling. Display and share diagrams with the class. Show the class the *2.b. Diagram of a Tomato Plant.*

3. **Whole group instruction.** Review concepts of germination and plant needs to grow.
4. **Explain.** Tell students that they will plant tomato seeds in a plastic cup and place it in their model greenhouse later. Let them know that germination will take about a week so they need to germinate the seeds.

Closure

1. **Review.** Review the plant parts and what observations students need to make next couple of weeks. Ask students to predict how much their plant will grow each day.
2. **Tie back to the engineering challenge.** Remind students that we are working toward successful greenhouse design. Learning background knowledge on plants will help us evaluate our first design and make improvements for redesign.

Assessments

Pre-Activity Assessment
Ask students about plants parts.

Activity Embedded Assessment
Make observations and label plant parts.

Post-Activity Assessment
Review the plant parts.

DUPLICATION MASTERS

- 2.a. Word bank

EDUCATOR RESOURCES

- 2.b. Diagram of a Tomato Plant

LESSON 2

Name________________________________ Date____________ Period _____

2.a. Word Bank

Root: In vascular plants, which are plants that have water and nutrients travel throughout the plant, the root is the organ of a plant that typically lies below the surface of the soil. The purpose of this organ is to absorb water and nutrients from the soil to feed the plant. Root hairs help with this function by increasing the surface area below the surface of the soil, and allow the plant to absorb more nutrients. Roots also help anchor the plant in the soil. The primary root is the initial root that grows from the tomato seed. Root hairs extend from the primary root. The root cap, which is the outermost part of the root, is responsible for helping the plant grow in the correct orientation, such as up towards the sun, for example.

Fruit: A fruit is a part of a flowering plant that consists of a mature ovary and seeds. This part of the plant can be fleshy, such as that seen in tomatoes, or hard, such as that seen in nuts. These fleshy fruits typically attract animals and people that can help spread these fruits—containing seeds—and thus disperse the plant to new locations. An example of this is when you throw away an apple core into a field, and thus allow a new apple tree to form.

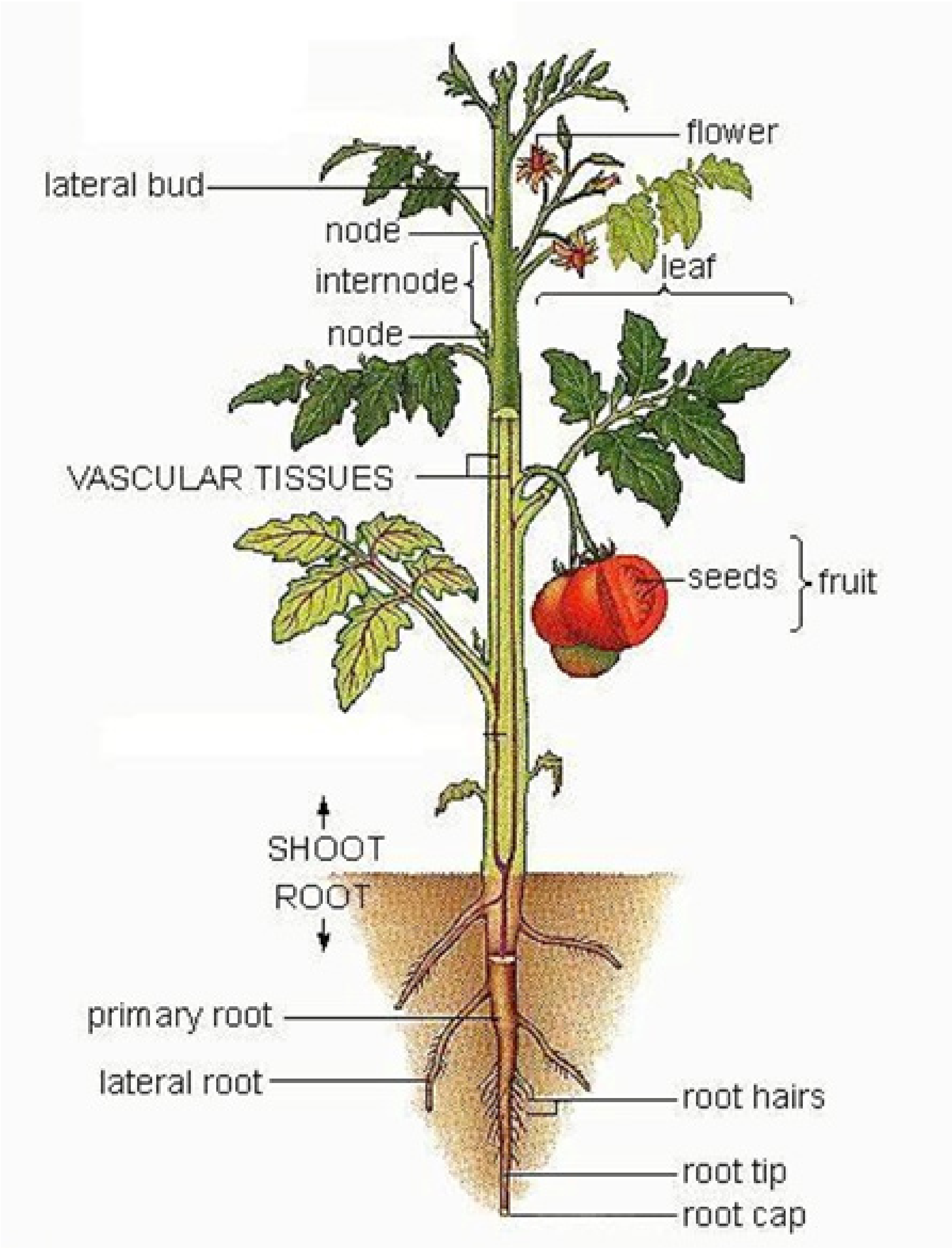
Stem: A stem is one of two main structural axes of a vascular plant, the other being the root. The stem is normally divided into nodes and internodes. The nodes hold buds which grow into one or more leaves; the internodes distance one node from another. The term “shoots” is often confused with “stems”; “shoots” generally refers to new fresh plant growth including both stems and other structures like leaves or flowers. In most plants stems are located above the soil surface but some plants have underground stems. A stem develops buds and shoots and usually grows above the ground. Inside the stem, water and nutrients move up and down the tissues of the vascular system.

Leaf: A leaf is typically a thin, flattened organ borne above ground and specialized for photosynthesis, which is the process by which plants convert sunlight into energy. This process is absolutely essential for plant survival. It is therefore important that the environment for the tomato plant allows for adequate sunlight, which will let the plant undergo adequate photosynthesis. Additionally, too much heat (above 95 degrees Fahrenheit) will waste the products of photosynthesis, and thus kill the plant.

Flower: The flower is responsible for the reproduction of the plant. Flowers exist as either male or females, and the gender will affect the structure of the flower. Male plants contain a stamen, which is the pollen-containing structure of male flowers; where female plants contain a pistil, which is the part of the female plant that contains the ovary. The flower also contains a sepal, which is located at the base of the flower and is responsible for protecting the flower as it buds.

https://ag.arizona.edu/pubs/garden/mg/botany/

2.b. Diagram of a Tomato Plant



LESSON 3 Testing Materials

Lesson Objectives
The student will be able to:
- Explore how greenhouse works.
- Investigate properties of materials.

Time Required
One 50-minute class period

Materials
- **Per classroom:** 6 6 in. x 6 in. Cardboard boxes, 6 Thermometer, 6-60 Watt bulbs, stop watches, 6 8 ½ in. Clamp lights, 5 Test materials- plastic wrap, bubble wrap, transparency sheet, page protector, plastic folder
- **Per group:** 1 6 in. x 6 in. Cardboard box, 1 Thermometer, 1-60 Watt bulb, 1 8 ½ in. clamp light,
- **Per student:** 1 Engineering Notebook*, 1 Copy of recording sheet (2.a) *

Standards Addressed
- Next Generation Science Standards: MS-LS1-4, MS-LS2-1, MS-ETS1-1
- Common Core State Standards - Mathematics: 5GA1, 5GA2

Key Terms
heat radiation, heat absorption, heat convection

Lesson Summary
This session will begin by reviewing plant needs and how to extend the growing season. Students will then test materials. They will record data and make claims based on their data. They will then begin to examine how they could utilize this phenomenon to extend the growing season for tomatoes in Minnesota.

Background
Teacher Background
- **Heat radiation**: This type of heat transfer can be observed on sunny days. Your face will feel warm when you are standing in the sun. The sunlight is absorbed by your face and warms your face, without warming the air around you. The energy from the sun that is absorbed by your face is called radiant energy or radiation. Radiation is the transfer of this heat energy by electromagnetic waves.
- **Heat absorption:** The absorption of heat through a substance. As a result the object changes in chemical physical appearance.
- **Heat convection:** Convection is the transfer of heat through the movement of a fluid, such as water or air. This type of heat transfer can occur in liquids and gases because they move freely, making it possible to set up warm or cold currents. Convection occurs naturally in the atmosphere on a warm, sunny day. As the earth's surface absorbs sunlight, certain portions of the surface absorb more than other portions. The earth's surface and the air near the surface heats unevenly. The warmest air expands, becomes less dense than the surrounding cooler air, becomes buoyant and rises. These rising "bubbles" of warm air, called thermals, act to transfer heat up into the atmosphere. Cooler, heavier air then flows toward the surface to replace the warm air that just rose. When the cooler air reaches the surface, it is warmed and it too eventually rises as a thermal. This circulation is referred to as a convective circulation or thermal cell.
- **How a greenhouse works:** The greenhouse effect as it relates to actual greenhouses works in the following way. A greenhouse reduces the rate at which thermal energy flows out of its structure, and it does this by impeding heat that has been absorbed from leaving its confines through convection. The material for greenhouse construction is typically glass or plastic so that sunlight can pass through it. This sunlight is integral to the greenhouse becoming warm, since it heats up the ground inside the greenhouse. In turn, the warm ground then warms up the air in the greenhouse, which keeps on heating the plants inside since it is confined within the structure of the greenhouse.

  Source: http://www.proflowers.com/blog/greenhouse-gardening-guide

Before the Activity
Gather materials: 6 small cardboard boxes and test materials. One box will be used as control where the top will be left open. Students will cover the top of each box with one of the five materials (plastic wrap, bubble wrap, transparency sheet, page protector, plastic folder). Prepare the boxes for the first measurement. Cover about 1/4th of the top of the boxes with materials. Tape the materials to the boxes. Make a small hole on the right or left side of each

box to insert a thermometer (including the control box). Place a heat lamp about 20 cm above each box (See *3.b. Set Up for Data Collection* pictures to help in your set up).

Classroom Instruction

Introduction

1. **Tie to engineering challenge. Ask:** *Have you ever wondered why it is warmer when you stand in a sunny place as opposed that is in the shade? Have you ever had food melt inside a car on a sunny day? Do you think the food would have melted as much if you had left the windows open? Why do you think this happens?* (Sun radiates heat that gets trapped in the car).

Activity

1. **Review the concepts.** Review with the students some of the things that they found out yesterday regarding the issues with growing tomatoes in Minnesota (limited growing season). Tell students today they are going to start testing materials.
2. **Tie back to the design challenge.** Remind students of the design problem. **Ask:** *How are we going to help the Farmers' Market Group and vendors solve their problem?*
3. **Introduce the concept. Ask:** *How do you think a greenhouse works?*
4. **Identify where they are in the engineering design process** (Learn). Remind students that an important part of the engineering design process is learning about the problem and ways to solve the problem. Explain students that they will learn about how greenhouse works and test materials, which will help them to design a successful greenhouse later in the unit. Ask students where they are in the engineering design process.
5. **Discuss the greenhouses.** Explain the class how greenhouse works and tell them today the class is going to work to test materials that can be used to build a greenhouse. **Ask:** *What are some materials you think we might be able to use to design a greenhouse that can trap heat?*
6. **Introduce the activity.** Tell students that they will test several materials today. Show students cardboard boxes you prepared. Divide students into 6 groups. Each group will get one of the boxes and collect data for 10 minutes.
7. **Collect and graph data.** Students will record temperature every minute. Have each group share their data on the board. Have students make graphs of their data and class data.
8. **Discussion.** Run a discussion about the data and graphs students created.

Closure

1. **Tie back to the engineering challenge. Ask:** *Based on what we learned today, what materials would work better for greenhouse design?*

Assessments

Pre-Activity Assessment
Ask students to write down if they know why a candy bar melts when inside a car on a sunny day.

Activity Embedded Assessment
Have students write down why they think certain boxes retained more heat than others.

Post-Activity Assessment
Summative: Have students write down how they could utilize this phenomenon (greenhouse) to extend the growing season for tomatoes in Minnesota.

DUPLICATION MASTERS

- 3.a. Recording sheet

EDUCATOR RESOURCES

- 3.b. Set up for Data Collection

LESSON 3

Name________________________________ Date___________ Period _____

3.a. Temperature Recording Sheet

Material Type ____

Room temperature ________°F

	1/4th of the top covered with the material	1/2 of the top covered with the material	Top covered with the material
Min	Temp (°F)	Temp (°F)	Temp (°F)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

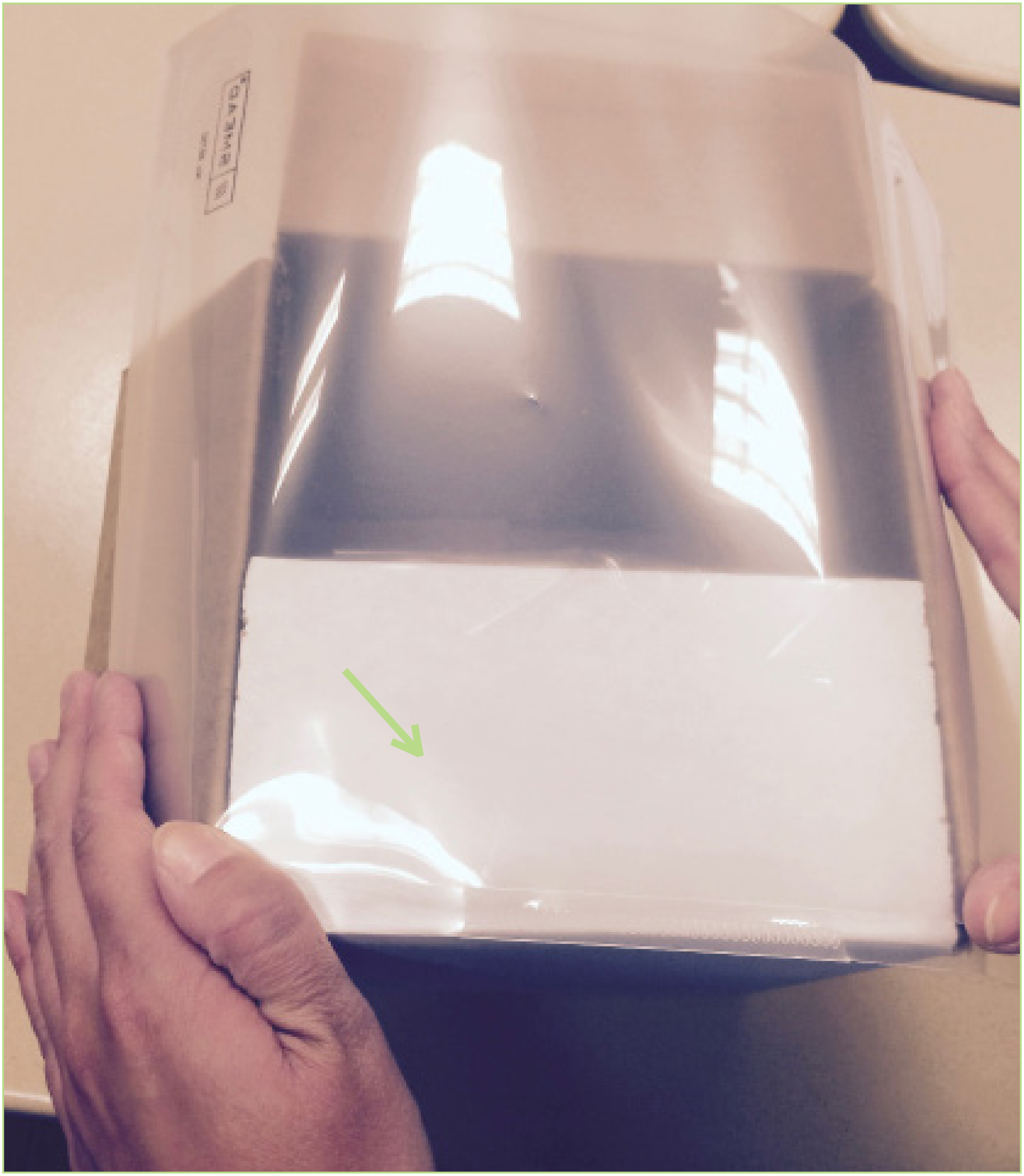
Temperature 10 minutes after turning off the light source:___°F
Observations:

3.b. Set Up for Data Collection

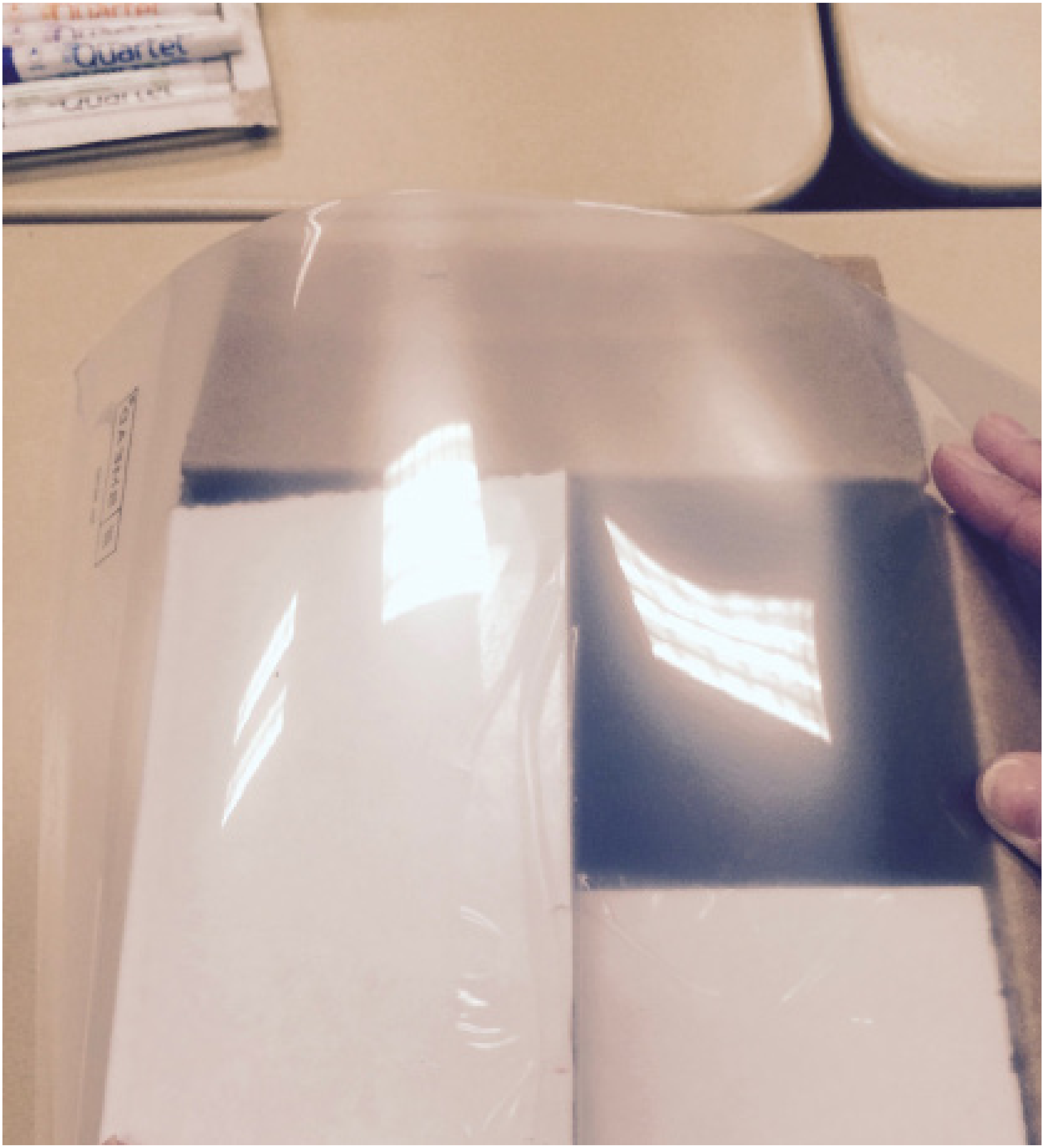
Thermometer

3.b. Set Up for Data Collection

3.b. Set Up for Data Collection



3.b. Set Up for Data Collection



3.b. Set Up for Data Collection

LESSON 4

Design and Cost Analysis of Greenhouse

Lesson Objectives
The student will be able to:
- Utilize their knowledge from the previous lessons to design a model greenhouse that will extend the growing season for tomatoes in Minnesota.
- Determine the surface area and materials costs.

Time Required
Two 50 min. class period

Materials
- **Per classroom:** 8 Calculators, 8 Metric rulers, 8 15-Centimeter grid transparencies, Calculators, Transparency markers
- **Per group:** 1 calculator, 1 Metric ruler, 1 15-Centimeter grid transparency, Transparency markers
- **Per student:** 1 Engineering Notebook*, 1 Copy of lesson worksheets (4.a. - 4.d.)*

Standards Addressed
- Next Generation Science Standards: MS-ETS1-1, MS-ETS1-2, MS-ETS1-4

Key Terms
design, cost analysis

Lesson Summary
Begin greenhouse design and cost analysis. Students will be given a shoe box and they will sketch their shape of the windows for the greenhouse. They can come up with as many windows as they wish, but they should make sure that they leave a 2 cm strip on the longer side of the box so as to insert a thermometer to measure the temperature inside the greenhouse. The students will decide on the materials that they plan to use for the windows. They will be given the scoring rubric and the list of material costs. The drawings will need to be made to scale. Students must submit plans to teacher before approval to build in Lesson 5.

Background
Teacher Background
Become familiar with the calculation of the area of the shapes (square, rectangle, triangle, a circle, trapezoid, and parallelogram).

Before the Activity
Get all materials ready.

Classroom Instruction
Introduction
1. **Tie to engineering challenge.** Ask students to state their challenge: Extend the growing season in Minnesota for tomatoes. Remind students that to meet this challenge we have decided to build a greenhouse. **Ask:** *How do you think a greenhouse can extend the growing season?* (Maintain a good growing temperature).

Activity
1. **Introduce the investigation.** Put sample materials at each group (3-4 students). Tell students that they will be using shoe boxes to construct their greenhouse, and remind them of the possible materials that they can use for the windows in the greenhouse.
2. **Identify where they are in the engineering process**. Ask students to identify where they are in the engineering design process (plan).
3. **Go over specifics of the engineering design challenge.** Pass out the *4.a. Cost List* and the *4.b. Scoring Rubric*. Explain the sheets to the students and make sure that they are clear about the challenge.
4. **Complete the engineering design sheet.** Distribute the *4.c. Engineering Design Sheet*. Inform students that they must draw out their design for the windows and list materials on the sheet. They are responsible for figuring out the area of the windows, the base area, and amount of tape needed. All parts of the diagram must be labeled including any materials used. Show general examples of drawings of both 2 and 3 dimensions.
5. **Document their evidence-based reasoning.** Pass out the *4.d. Evidence-Based Reasoning Sheet* and ask the students to draw their sketch of the greenhouse providing evidence and reasons for why their greenhouse design should be picked. You may use the *4.d. Evidence-Based Reasoning Poster with Explanations* educator resource to help students understand how to fill out the Evidence-Based Reasoning sheet.
6. **Engineering notebook entry.** Have students answer the following

questions in their Engineering Notebook:
- *What are the pros and cons of each of your solutions?*
- *Which solution did your team choose and why?*

Closure

1. **Tie back to the engineering challenge.** Have each group share what seemed to go well in their design process and what were some challenges.

Assessments

Pre-Activity Assessment
Ask students if they can determine the area of a given shape (triangle and square)

Activity Embedded Assessment
Observe students as they are determining surface area of their windows.

Engineering Notebook: 2 Plan Questions

Post-Activity Assessment
Check student calculations of area, and costs of structure. Check their cost calculations.

DUPLICATION MASTERS
- 4.a. Cost List
- 4.b. Scoring Rubric
- 4.c. Engineering Design Sheet
- 4.d. Evidence-Based Reasoning Sheet

EDUCATOR RESOURCES
- 4.d. Evidence-Based Reasoning Poster with Explanations

LESSON 4

Name________________________________ Date___________ Period _____

4.a. Cost List

Formula for Calculating Area of Different Shapes:

- Square: Length x Width
- Rectangle: Length x Width
- Triangle: 0.5 x Base x Height

Cost per cm^2 of Window Materials:

- Saran Wrap: $0.25
- Transparency: $0.15
- Plastic Folder: $0.20
- Sheet Protector: $0.30
- Bubble Wrap: $0.20
- Aluminum Foil: $0.10
- White Felt: $0.15

Name________________________________ Date____________ Period ______

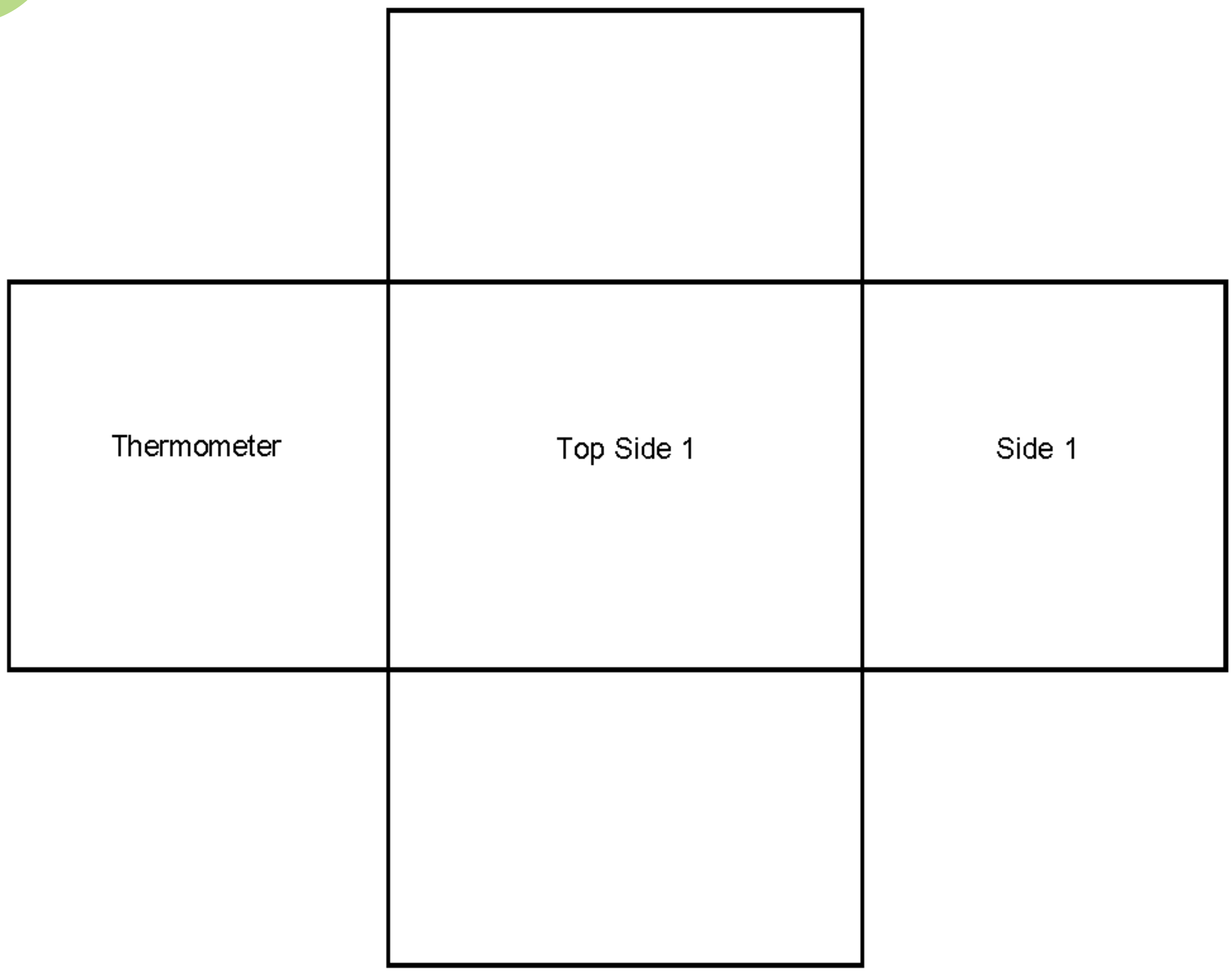
4.b. Scoring Rubric

	10 Points	5 Points	1 Point
Cost	$20 or less	$20.01 to $59.99	$60 or more
Temperature inside the greenhouse	Temperature in the greenhouse is between 65°F and 85°F		Temperature in greenhouse is either over 95°F or less than 65°F
Plant growth	Above 10cm	Between 5cm and 10cm	Less than 5cm

LESSON 4

Name________________________________ Date___________ Period _____

4.c. Engineering Design Sheet



Top

Shape:______________ Area: _______cm^2 Material: _________

Cost per cm^2: ___________

Total Cost of Window = Area x Cost per cm^2 = $__________

Shape:______________ Area: _______cm^2 Material: _____________

Cost per cm^2: ___________

Total Cost of Window = Area x Cost per cm^2 = $__________

Total cost of all windows in Top = ____________

LESSON 4

Name______________________________ Date__________ Period _____

4.c. Engineering Design Sheet

Side 1

Shape:_______________ Area: ________cm^2 Material: ______________

Cost per cm^2: ____________

Total Cost of Window = Area x Cost per cm^2 = $___________

Shape:_______________ Area: ________cm^2 Material: ______________

Cost per cm^2: ____________

Total Cost of Window = Area x Cost per cm^2 = $___________

Total cost of all windows in Side 1 = _____________

Side 2

Shape:_______________ Area: ________cm^2 Material: ______________

Cost per cm^2: ____________

Total Cost of Window = Area x Cost per cm^2 = $___________

Shape:_______________ Area: ________cm^2 Material: ______________

Cost per cm^2: ____________

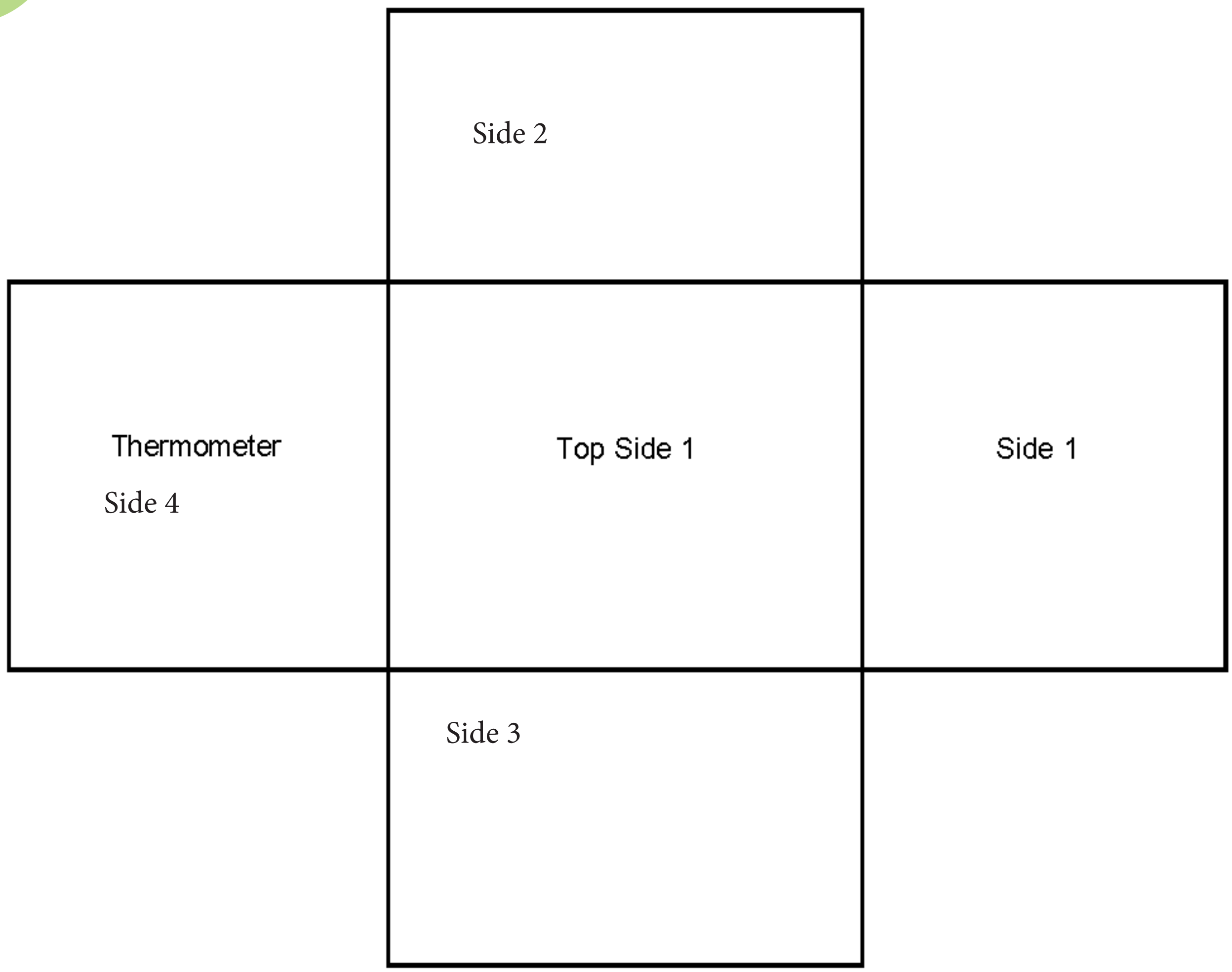
Total Cost of Window = Area x Cost per cm^2 = $___________

Total cost of all windows in Side 2 = _____________

LESSON 4

Name________________________________ Date___________ Period _____

4.c. Engineering Design Sheet



Side 3

Shape:_______________ Area: ________cm² Material: __________

Cost per cm²: ____________

Total Cost of Window = Area x Cost per cm² = $___________

Shape:_______________ Area: ________cm² Material: ______________

Cost per cm²: ____________

Total Cost of Window = Area x Cost per cm² = $___________

Total cost of all windows in Top = _____________

LESSON 4

Name____________________________________ Date____________ Period _____

4.c. Engineering Design Sheet

Side 4

Shape:_______________ Area: ________cm^2 Material: ______________

Cost per cm^2: ____________

Total Cost of Window = Area x Cost per cm^2 = $___________

Shape:_______________ Area: ________cm^2 Material: ______________

Cost per cm^2: ____________

Total Cost of Window = Area x Cost per cm^2 = $___________

Total cost of all windows in Side 1 = _____________

Total Cost of Greenhouse

Top =

Side 1 =

Side 2 =

Side 3 =

Side 4 =

Total =

Temperature Performance

Temperature after 10 minutes of Sunlight: ___________

Temperature after 10 minutes of Dark: ___________

LESSON 4

Name_______________________________ Date___________ Period _____

4.d. Evidence-Based Reasoning Sheet

Problem with Criteria & Constraints (What do you need to worry about?)	
Problem: ____ ____ **Criteria:** ____ **Constraints:** ____	
Simplifying Assumptions (What do you not need to worry about?)	
____ ____	
Plan (Design Idea)	**Data/Evidence** (Facts)
	____________________ ____________________ ____________________ ____________________ ____________________ ____________________ ____________________ ____________________ ____________________ ____________________ ____________________
Explanation, Justification, Reasoning (Why do you think this will work?)	
____ ____ ____ ____ ____ ____ ____	

4.d. Evidence-Based Reasoning

Poster with Explanation

Problem with Criteria & Constraints (What do you need to worry about?)

Problem: the engineering problem the client asked you to solve

Criteria: the requirements, or goals, of the designed solutions

Constraints: things that limit design possibilities

Simplifying Assumptions (What do you not need to worry about?)

Ways to make a complex problem simpler

Plan (Design Idea)	**Data/Evidence** (Facts)
• Description of the design • Drawings of the design, different views • Dimensions (sizes) • Label materials in design (show where they are used) • Interesting features	Observations and data that show why you think your design will work Examples: • Data from earlier lessons • Total cost of design • Data from prototype testing

Explanation, Justification, Reasoning (Why do you think this will work?)

Complete sentences that state why you think your design will be successful. These sentences should refer to the problem, criteria, constraints, solution, and data/evidence.

LESSON 5

Construct and Test Greenhouses

Lesson Objectives
The student will be able to:
- Construct and test their model greenhouses based on their design from yesterday.
- Test their designs to examine how they maintain the optimal temperature in a 10-minute period while they are exposed to light and then continue to monitor 10 minutes after light source is off.
- Determine the effectiveness of their greenhouse.

Time Required
Two 50-minute class periods

Materials
- See Overview

Standards Addressed
- NGSS: List performance expectation
- CCSS-Math: List domain and standard number

Key Terms
scoring rubric

Lesson Summary
Students will construct greenhouses based on their plan. They will then test their designs to examine how they maintained the optimal temperature in a 10-minute period while they are exposed to light and then continue to monitor 10 minutes after light source is off. Students will graph these data and examine how well they meet the needs of the challenge. Students will share designs and their effectiveness.

Background
Teacher Background
Research greenhouse designs.

Before the Activity
Have a material station set up.

Classroom Instruction
Introduction
1. **Tie back to the engineering challenge.** Ask students to state the design challenge once again.
2. **Identify where they are in the engineering design process.** (Try and test) **Say:** Y*esterday, we completed the planning step. Now, we are ready to try and test them.* Tell students that their first idea might not work, and that they will be redesigning their greenhouses to make them better.

Activity
1. **Introduce the activity.** They are to design a greenhouse and utilize equipment to build their greenhouse. They will work with their groups from the previous lesson. The goal will be to have the temperature 10-15 degrees above room temperature after 10 minutes.
2. **Tie to engineering design. Ask:** *Where do you think we are in the engineering design process?* (try) Have them update their location on their slider.
3. **Demonstrate materials.** Introduce students to the sun station set-up. Light should be placed about 20 cm from table up on clamp stand. Place front edge of greenhouse on table with the edge 10 cm from clamp stand. Show students the materials station. Pass out the design sheets from the previous lesson and have students begin construction.
   Note: Do not allow construction until you have approved the group plan.
4. **Assess students as they try their design.** Use the *5.a. Teacher Observation Protocol: Try Lesson* sheet to assess students as they design in their teams.
5. **Have students build their greenhouse.** Allow approximately 1-2 class periods for construction.
   Note: As the students start working on their design for the windows, help them to start cut the windows of the greenhouse with a box cutter.
6. **Demonstrate the testing of the greenhouse design.** Students will place a thermometer inside their constructed greenhouse (shoe box). They will need to make sure that they can see the reading of the temperature on the inside of the box.
7. **Test their designs.** Have students test their greenhouse structures.

Construct and Test Greenhouses

Remind them about where they are in the design process and update slider positions. Pass out the *5.b. Greenhouse Testing Recording Sheet* to each student.

8. **Data collection.** The students will record the temperature after every minute for 10 minutes after the light is turned on and after the light is turned off. Students will then figure their point total based on the scoring rubric. For a high score, temperature in the greenhouses should be between 65°F and 95°F. Students are asked to collect cooling off temperature to understand the need for continuing light source.
9. **Assess students as they test their design.** Use the *5.c. Teacher Observation Protocol: Test Lesson* sheet to assess students as they test their design.
10. **Document the results.** Have students write their observations and results in their Engineering Notebook. They are to answer three questions.
    - *What have you learned about the performance of your solution from your test results?*
    - *What changes will you make to your solution based on the results of your test? Explain why you want to make those changes.*
    - *What improvements will you make based on what you have learned about temperature and light? Explain why you want to make those changes.*
11. **Graph the testing data.** If time allows, ask students to graph their data.
12. **Collect data on tomato plants in the greenhouse designs.** Have students place the cups with tomato seedlings inside theri greenhouses. Students use grow lights to speed up the growth process. Make sure students will water their plants at the same time and all use the same amount of water. Have students fill in the *5.d. Growth and Development of Tomato Plants* sheet to record their observations during the next two weeks. Each day remind students of the challenge and why they are collecting data.

Closure

1. **Tie back to the engineering challenge.** Each group will share their design with the rest of the class and share out their results. Ask students why they made some of the decisions they did during the design process.

Assessments

Pre-Activity Assessment

Have each group explain why they think that their design will be effective in getting the temperature above the ambient temperature.

Activity Embedded Assessment

Observe how students are recording and plotting data during the investigation.

While students are constructing and testing their greenhouses, walk around to each team and assess their progress with the Teacher Observation Protocol: Try Lesson sheet and the Teacher Observation Protocol: Test Lesson sheet, respectively.

Post-Activity Assessment

Have each student write about the effectiveness of their greenhouse. This piece should include a rationale on why or why not it may have been effective.

DUPLICATION MASTERS

- 5.b. Greenhouse Testing Recording Sheet
- 5.d. Growth and Development of Tomato Plants

EDUCATOR RESOURCES

- 5.a. Teacher Observation Protocol: Try Lesson
- 5.c. Teacher Observation Protocol: Test Lesson

5.a. Teacher Observation Protocol: Try Lesson

Directions:
This is an observation assessment. The main purpose of this assessment is to observe evidence that student teams are working together to make their solution. In addition, this is opportunity to further assess that students are making design-decisions based on understanding the problem.

- **Part 1:** As you walk around to each team, please put a check by the behaviors you observe.
- **Part 2:** Interact with each team to assess their progress on the project. You may choose to ask some of the following questions or your own questions. You may also choose to add (or not) your own additional teaming-related assessment, as you deem appropriate. There is space for you to take notes of your observations.

Part 1: Behaviors

☐ All team members are on-task to make/try their solution.

☐ One or more team members are not on-task.

Notes:

☐ Team has made appropriate progress on their solution.

☐ Team is struggling to make their solution.

Notes:

☐ Team is making/made a solution directly related to problem.

☐ Team is making/made a something unrelated to problem.

Notes:

5.a. Teacher Observation Protocol: Try Lesson

Part 2: Question Prompts

Note: These questions can be used to further draw out and scaffold students' evidence-based reasoning. While the main purpose of these questions is to assess students' reasoning, it is also appropriate to interact with students/ question for the purpose to support learning. Please note student responses below.

1. Can you tell me about your solution? What are you designing?

2. What were some of the other solution ideas you generated? How well did they address the problem?

3. How did you decide to move forward with this idea? What evidence do you have that your design will solve the problem for the client?

LESSON 5

Name________________________________ Date___________ Period _____

5.b. Greenhouse Testing Recording Sheet

Outside/Ambient Temperature: ____ °F

Temperature under light

Time (minutes)	Temperature (°F)
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Temperature difference from start to 10 minutes:

____ °F

Cooling Temperature after light is turned off:

____ °F

5.c. Teacher Observation Protocol: Test Lesson

Directions:
This is an observation assessment. The main purpose of this assessment is to observe evidence that student teams are working together to make their solution. In addition, this is opportunity to further assess that students are making design-decisions based on understanding the problem.

- **Part 1:** As you walk around to each team, please put a check by the behaviors you observe.
- **Part 2:** Interact with each team to assess their progress on the project. You may choose to ask some of the following questions or your own questions. You may also choose to add (or not) your own additional teaming-related assessment, as you deem appropriate. There is space for you to take notes of your observations.

Part 1: Behaviors

☐ All team members are on-task to make/try their solution.

☐ One or more team members are not on-task.

Notes:

☐ Team has made appropriate progress on their solution.

☐ Team is struggling to make their solution.

Notes:

☐ Team is making/made a solution directly related to problem.

☐ Team is making/made a something unrelated to problem.

Notes:

LESSON 5

Name________________________________ Date____________ Period ______

5.d. Growth and Development of Tomato Plants

Day	Temperature inside greenhouse (°F)	Number of leaves	Height of the plant	General appearance
Day 1				

LESSON 5

Name________________________________ Date____________ Period ______

5.d. Growth and Development of Tomato Plants

Day	Temperature inside greenhouse (°F)	Number of leaves	Height of the plant	General appearance

LESSON

6 Redesign and Cost Analysis of Greenhouse

Lesson Objectives

The student will be able to:

- Utilize their knowledge from the previous lesson to redesign a greenhouse that will extend the growing season for tomatoes in Minnesota.
- Determine the surface area and materials costs.

Time Required

One 50-minute class period

Materials

- **Per classroom:** 8 Calculators, 8 Metric rulers, 8 15 Centimeter grid transparencies, Transparency markers
- **Per group:** 1 Calculator, 1 Metric ruler, 1 15 Centimeter grid transparencies, Transparency markers
- **Per student:** 1 Engineering Notebook*

Standards Addressed

- Next Generation Science Standards: MS-ETS1-1, MS-ETS1-2, MS-ETS1-4

Key Terms

redesign

Lesson Summary

Students will use the prior knowledge that they obtained during previous lessons to work on their redesign. They should examine the effectiveness of their previous greenhouse. Students will then work on their redesign and come up with a new design that will be more effective based on the challenge. Students can also examine how they could increase their point total. All redesigns must be approved by the teacher.

Background

Teacher Background

Review the engineering design process.

Before the Activity

Make sure students have access to materials and data from previous lessons.

Classroom Instruction

Introduction

1. **Tie back to the engineering challenge.** Ask students to state their challenge: Extend the growing season in Minnesota for tomatoes. Remind students that to meet this challenge we have decided to build a greenhouse.
2. **Identify where they are in the engineering design process. (**Redesign - which will require a new plan, try, test, decide cycle). Ask students to think about their first design and structure. Prepare students for the idea that they need to redesign to improve their first design.
3. **Help students recall their previous ideas.** Have students review the answers to their 3 notebook prompts from the end of Lesson 5 regarding possible redesign ideas. Ask students how they might redesign.

Activity

1. **Activate prior knowledge.** Remind students of what they learned about plants in Lesson 2. Ask students to share plant growth data they collected in Lesson 5. Discuss the results.
2. **Introduce the planning stage for the redesign.** Put sample materials at each group (3-4 students). Tell students that these are the materials that they will be using for their redesign.
3. **Remind students of the specifics of the engineering design challenge.** Pass out the *6.a. Cost List* and the *6.b. Scoring Rubric*. Explain them to the students making sure that they are clear about the challenge.
4. **Complete the redesign sheet.** Distribute the *6.c. Engineering Redesign Sheet.* Inform students that they must draw out their design for their greenhouse windows and list materials on the sheet. They are responsible for figuring out the area of the windoes, the base area, and the amount of tape needed. All parts of the diagram must be labeled including any materials used. Show general examples of drawings of both 2 and 3 dimensions. Allow time for students to work on redesigns. Continue to support students as they need assistance in finding the area of different shapes.
5. **Document their evidence-based reasoning.** Pass out the *6.d. Evidence-Based Reasoning Sheet* and ask the students to draw their sketch of the

greenhouse providing evidence and reasons for why their greenhouse design should be picked. You may use the *4.d. Evidence-Based Reasoning Poster with Explanations* educator resource to help students understand how to fill out the Evidence-Based Reasoning sheet.

Closure

1. **Share decisions.** Have each group share what seemed to go well in their redesign process and what were some challenges.

Assessments

Pre-Activity Assessment

Engineering Notebook: 3 test questions related to how students could improve their solution. This happened at the end of Lesson 5.

Activity Embedded Assessment

Teacher Observation Protocol: Observe students as they work on their redesign to see if they are addressing their improvements.

Post-Activity Assessment

Check student calculations of both surface area, costs and base area of structure.

DUPLICATION MASTERS

- 6.a. Cost List
- 6.b. Scoring Rubric
- 6.c. Engineering Redesign Sheet
- 6.d. Evidence-Based Reasoning Sheet

LESSON 6

Name________________________________ Date___________ Period _____

6.a. Cost List

Formula for Calculating Area of Different Shapes:

- Square: Length x Width
- Rectangle: Length x Width
- Triangle: 0.5 x Base x Height

Cost per cm^2 of Window Materials:

- Saran Wrap: $0.25
- Transparency: $0.15
- Plastic Folder: $0.20
- Sheet Protector: $0.30
- Bubble Wrap: $0.20

LESSON 6

Name________________________________ Date__________ Period _____

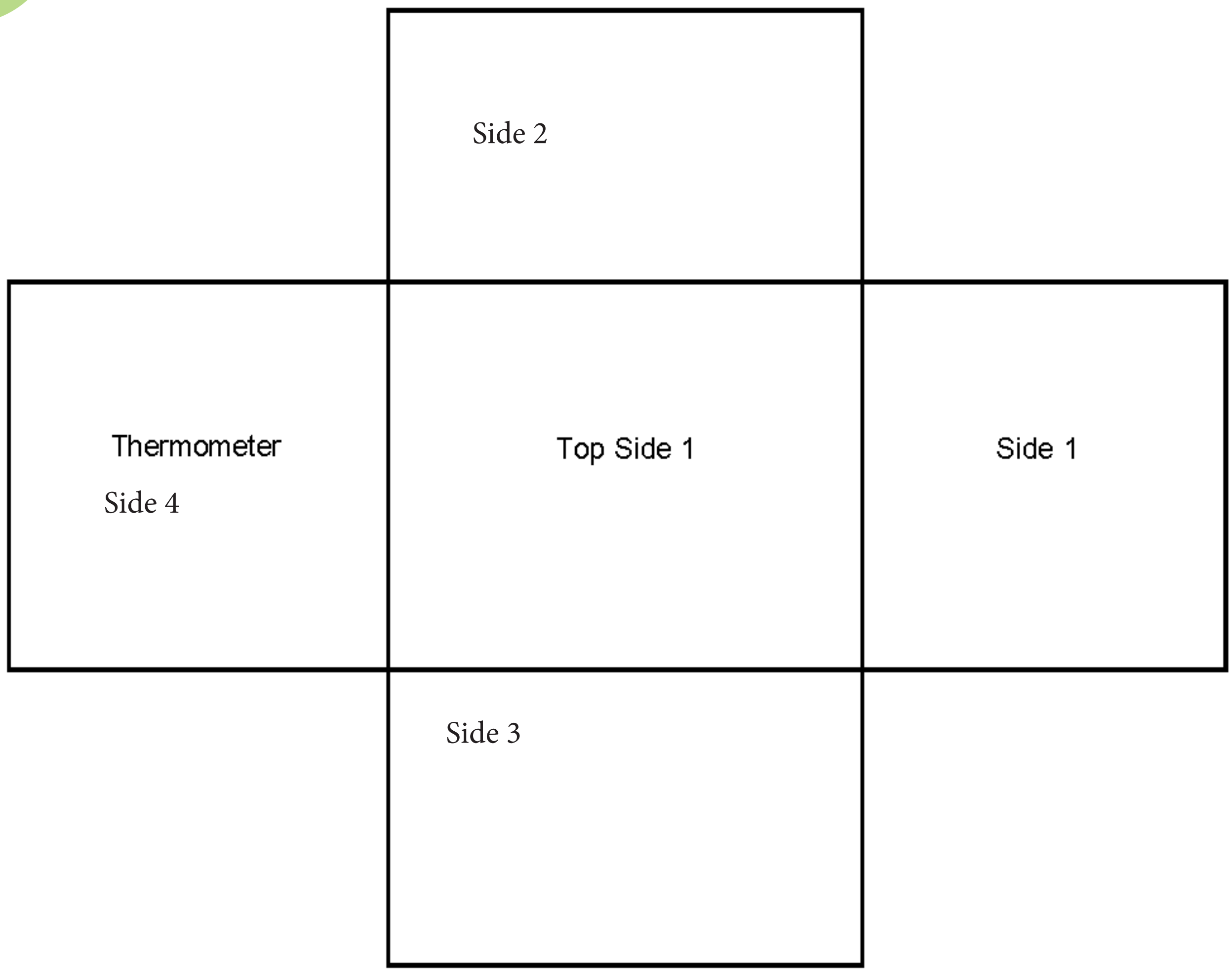
6.b. Scoring Rubric

	10 Points	5 Points	1 Point
Cost	$20 or less	$20.01 to $59.99	$60 or more
Temperature inside the greenhouse	Temperature in the greenhouse is between 65^0C and 85^0C		Temperature in greenhouse is either over 95^oC or less than 65^oC
Plant growth	Above 10cm	Between 5cm and 10cm	Less than 5cm

LESSON 6

Name_________________________________ Date____________ Period _____

6.c. Engineering Redesign Sheet



Top

Shape:_______________ Area: ________cm² Material: __________

Cost per cm²: ____________

Total Cost of Window = Area x Cost per cm² = $___________

Shape:_______________ Area: ________cm² Material: ______________

Cost per cm²: ____________

Total Cost of Window = Area x Cost per cm² = $___________

Total cost of all windows in Top = _____________

LESSON 6

Name________________________________ Date__________ Period _____

6.c. Engineering Redesign Sheet

Side 1

Shape:______________ Area: ________cm^2 Material: ______________

Cost per cm^2: ____________

Total Cost of Window = Area x Cost per cm^2 = $__________

Shape:______________ Area: ________cm^2 Material: ______________

Cost per cm^2: ____________

Total Cost of Window = Area x Cost per cm^2 = $__________

Total cost of all windows in Side 1 = _____________

Side 2

Shape:______________ Area: ________cm^2 Material: ______________

Cost per cm^2: ____________

Total Cost of Window = Area x Cost per cm^2 = $__________

Shape:______________ Area: ________cm^2 Material: ______________

Cost per cm^2: ____________

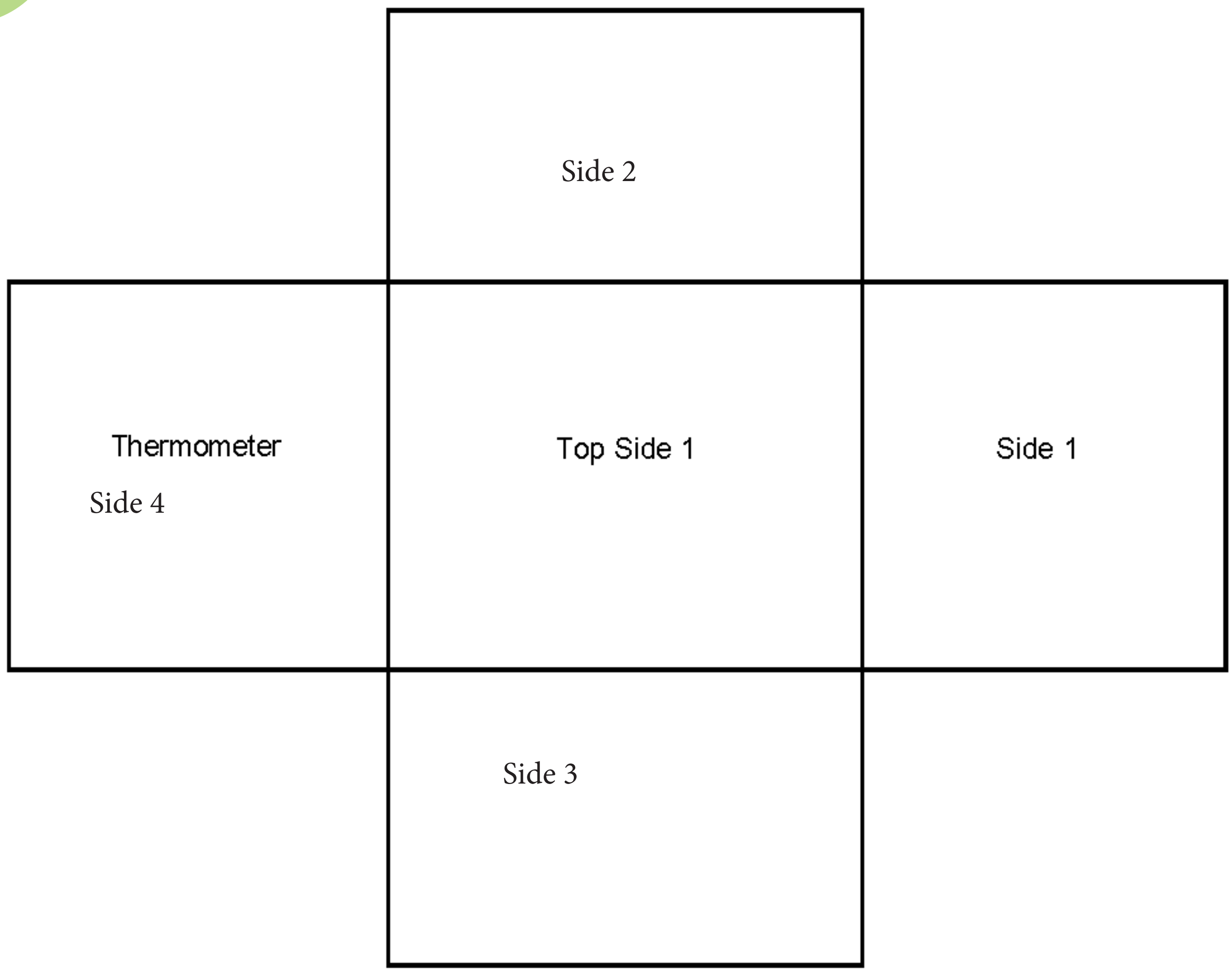
Total Cost of Window = Area x Cost per cm^2 = $__________

Total cost of all windows in Side 2 = _____________

LESSON 6

Name________________________________ Date___________ Period _____

6.c. Engineering Redesign Sheet



Side 3

Shape:______________ Area: ________cm^2 Material: _____________

Cost per cm^2: ___________

Total Cost of Window = Area x Cost per cm^2 = $__________

Shape:______________ Area: ________cm^2 Material: _____________

Cost per cm^2: ___________

Total Cost of Window = Area x Cost per cm^2 = $__________

Total cost of all windows in Side 3 = ____________

LESSON 6

Name________________________________ Date__________ Period ____

6.c. Engineering Redesign Sheet

Side 4

Shape:______________ Area: ________cm^2 Material: _____________

Cost per cm^2: ___________

Total Cost of Window = Area x Cost per cm^2 = $__________

Shape:______________ Area: ________cm^2 Material: _____________

Cost per cm^2: ___________

Total Cost of Window = Area x Cost per cm^2 = $__________

Total cost of all windows in Side 4 = ____________

Total Cost of Greenhouse

Top =

Side 1 =

Side 2 =

Side 3 =

Side 4 =

Total =

Temperature Performance

Temperature after 10 minutes of Sunlight: __________

Temperature after 10 minutes of Dark: __________

LESSON 6

Name________________________________ Date___________ Period _____

6.d. Evidence-Based Reasoning Sheet

Problem with Criteria & Constraints (What do you need to worry about?)

Problem:____

____

Criteria: ____

Constraints: ____

Simplifying Assumptions (What do you not need to worry about?)

____

____

Plan (Design Idea)	**Data/Evidence** (Facts)

Explanation, Justification, Reasoning (Why do you think this will work?)

____

____

____

____

____

____

____

LESSON 7

Build and Test Redesign

Lesson Objectives
The student will be able to:
- Construct and test their model greenhouses based on their redesign.
- Record temperature inside of the greenhouse over a 10-minute period after the light is turned on and again after the light is turned off.
- Determine the effectiveness of their redesigned greenhouse.

Time Required
Two 50-minute class periods

Materials
- See Overview

Standards Addressed
- NGSS: MS-ETS1-1, MS-ETS1-2, MS-ETS1-4
- CCSS-Math: 5GA.1, 5GA.2

Key Terms
engineering design process, redesign

Lesson Summary
Students will use their redesign to gather materials and construct their improved model. They will then test their improved designs to examine how they maintain the optimal temperature in a 10 minute period while they are exposed to light and then continue to monitor after 10 minutes after light source is off. Students will graph this data and examine how well it meets the needs of the challenge. Students will share designs and the effectiveness.

Background
Teacher Background
Review types of greenhouses.

Before the Activity
Testing stations and material stations should be set up.

Classroom Instruction
Introduction
1. **Tie it back to the engineering challenge.** Ask students to state the design challenge once again. They are to design a greenhouse and utilize equipment to build their greenhouse. They will work on constructing their redesign with their groups from the previous lesson. The goal will be to have the temperature 10-15 degrees above room temperature after 10 minutes.

Activity
1. **Introduce the activity and materials.** Reintroduce the sun station set-up from Lesson 3 (see *3.b. Set Up for Data Collection* for more information). Place light 20 cm from table up on a clamp stand. Place front edge of greenhouse on table with the edge 10 cm from clamp stand. Show students the materials station. Have the students review their *6.c. Engineering Redesign Sheets* from the previous lesson and have students have students begin construction.
2. **Have students build their redesigned greenhouses.** Allow approximately 25 minutes (possibly longer) for construction.
3. **Assess students as they try their redesign.** Use the 7.a. *Teacher Observation Protocol: Redesign Try* sheet to assess students as they try their redesign in their teams.
4. **Test their new designs.** Have students test their greenhouse structures. Remind them about where they are in the design process and update slider positions. Pass out the *7.b. Greenhouse Testing Recording Sheet* to each student. Students will place a thermometer inside. They will need to make sure that they can see the reading of the temperature on the inside of the box.
5. **Assess students as they test their redesign.** Use the *7.c. Teacher Observation Protocol: Redesign Test* sheet to assess students as they test their design in their teams.
6. **Record their data.** The students will record the temperature after every minute for 10 minutes. Students will continue to collect data every 10 minutes after the light is turned off. Students will then figure their point total based on the scoring rubric.

Build and Test Redesign

7. **Engineering notebook entry.** Ask students to complete the *Redesign Questions in their Engineering Notebook*.
   - *In what ways does your solution meet the criteria and constraints of the problem?*
   - *In what ways does your solution not yet meet the criteria and constraints of the problem?*
   - *Go back and look at how you described the problem right after talking with the client. How would you change your description of the problem now that you have planned, tried, and tested a solution? (Think about criteria, constraints, client need, and/or things you need to learn.)*

Closure

1. **Share.** Each group will share their redesign with the rest of the class and share out their results. Ask students why they made some of the decisions they did during the design process. Have student identify where they are currently on the engineering design process.

Assessments

Pre-Activity Assessment

Formative: Each group explains why their redesign will be effective in getting the temperature to 10-15 degrees above the ambient temperature.

Activity Embedded Assessment

Observe how students are recording and plotting data during the investigation and the effectiveness their redesign.

While students are building, walk around to each team and assess their progress with the *Teacher Observation Protocol: Try Lesson* sheet and the *Teacher Observation Protocol: Redesign Test Lesson* sheet.

Post-Activity Assessment

Students write in their notebooks about the effectiveness of their redesigned greenhouse including a rational of why or why not it may have been effective. Students are to answer 3 *Redesign Questions in their Engineering Notebooks* regarding based on evaluating their redesign.

DUPLICATION MASTERS

- 7.b. Greenhouse Testing Recording Sheet

EDUCATOR RESOURCES

- 7.a. Teacher Observation Protocol: Redesign Try
- 7.c. Teacher Observation Protocol: Redesign Test

LESSON 7

Name________________________________ Date___________ Period _____

7.a. Teacher Observation Protocol: Redesign Try

Directions:
This is an observation assessment. The main purpose of this assessment is to observe evidence that student teams are working together to make their solution. In addition, this is opportunity to further assess that students are making design-decisions based on understanding the problem.

- **Part 1:** As you walk around to each team, please put a check by the behaviors you observe.
- **Part 2:** Interact with each team to assess their progress on the project. You may choose to ask some of the following questions or your own questions. You may also choose to add (or not) your own additional teaming-related assessment, as you deem appropriate. There is space for you to take notes of your observations.

Part 1: Behaviors

☐ All team members are on-task to make/try their solution.

☐ One or more team members are not on-task.

Notes:

☐ Team has made appropriate progress on their solution.

☐ Team is struggling to make their solution.

Notes:

☐ Team is making/made a solution directly related to problem.

☐ Team is making/made a something unrelated to problem.

Notes:

LESSON 7

Name______________________________________ Date____________ Period _____

7.a. Teacher Observation Protocol: Redesign Try

Part 2: Question Prompts

Note: These questions can be used to further draw out and scaffold students' evidence-based reasoning. While the main purpose of these questions is to assess students' reasoning, it is also appropriate to interact with students/ question for the purpose to support learning. Please note student responses below.

1. Can you tell me about your solution? What are you designing?

2. What were some of the other solution ideas you generated? How well did they address the problem?

3. How did you decide to move forward with this idea? What evidence do you have that your design will solve the problem for the client?

LESSON 7

Name________________________________ Date___________ Period _____

7.b. Greenhouse Testing Recording Sheet

Outside/Ambient Temperature: ____ °F

Temperature under light

Time (minutes)	Temperature (°F)
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Temperature difference from start to 10 minutes:

____°F

Cooling Temperature after light is turned off:

____°F

LESSON 7

Name______________________________ Date__________ Period _____

7.c. Teacher Observation Protocol: Redesign Test

Directions:
This is an observation assessment. The main purpose of this assessment is to observe whether teams are testing their improved solution and analyzing results. In addition, this is opportunity to further assess that students are making design-decisions based on understanding the problem.

- **Part 1:** As you walk around to each team, please put a check by the behaviors you observe.
- **Part 2:** Interact with each team to assess their progress on the project. You may choose to ask some of the following questions or ask your own questions. You may also choose to add (or not) your own additional teaming-related assessment, as you deem appropriate. There is space for you to take notes of your observations.

Part 1: Plan/Try Behaviors

- ☐ All team members are on-task to retest solution.
- ☐ One or more team members are not on-task.

Notes:

- ☐ Team has attempted to improve performance of solution.
- ☐ Unclear what improvements team made.

Notes:

Part 2: Question Prompts During Retest

Note: These questions can be used to further draw out and scaffold students' evidence-based reasoning. While the main purpose of these questions is to assess students' reasoning, it is also appropriate to interact with students/ question for the purpose of supporting learning.

6. What did you find out from testing?

7. How did you interpret the findings from your tests? What do you think the results mean?

8. How did you decide what could improve your solution's performance?

LESSON 8 Communication to Client

Lesson Objectives
The student will be able to:
- Work in teams to communicate and justify their overall design to the client.

Time Required
One 50-minute class period

Materials
- **Per classroom:** none
- **Per group:** Data from previous lessons, Laptop or iPad to type memo* (not required), Poster paper* (not required)
- **Per student:** Engineering notebooks*

Standards Addressed
- Next Generation Science Standards: MS-LS1-4, MS-LS2-1, MS-ETS-1-3
- Common Core Mathematics: 5GA.1, 5GA.2

Key Terms
justification

Lesson Summary
Students will work in teams to communicate with client the overall problem, a claim on why their design is successful, evidence to support the claim, an explanation for why their design should be selected, and addressing any weaknesses in their design. Students should use evidence to support all claims. Students will be asked to complete the final evidence-based reasoning sheet for the client.

Background
Teacher Background
None

Before the Activity
- To finish out the unit, students will report their design, data, and justifications to their client. Allow students present their communication to the class.
- It may be helpful to generate your own list of ways you want students to present their information. Be sure to clearly review what components they need along with how they will be critiqued.

Classroom Instruction
Introduction
1. **Identify where they are in the engineering process.** (Communicate) Tell students that they will work in their teams to provide their client with a final design communication in the form of their choice.

Activity
1. **Introduce the activity.** Remind students that this will be the justification for your final design to your client. Be sure to meet all rubric criteria. The report will include sketches of your design, observations, results from your experiments, and your budget. Remind students that drawings or sketches should be a clear and complete record of their design. Students should also explain how they think they met the client needs. The students can do this through completion of the *8.a. Evidence-Based Reasoning - Solution Graphic.*
2. **Share evaluation criteria.** Share the criteria that you will use to evaluate the reports: Clarity, completeness, accuracy, and appropriate use/application of science and math content. Share the *8.b. Final Communication to the Client Rubric* with the students.
3. **Complete the *8.a. Evidence-Based Reasoning - Solution Graphic.*** *Provide students time to do this.*
4. **Share out with the class.** Ask students to share their reports.

Closure
1. **Complete the science assessment.** Administer the *8.c. Science Assessment.*
2. **Respond to question prompts in engineering notebook.** After presenting their solution to the client students should answer the following questions on their own. Then, in their teams, students should share their response and discuss. Below their response they should write their revised

answer to each question, based on their discussion with their team. Students may use a different color writing utensil to distinguish their answer and how it changed after talking with teammates.

- *Look back in your Engineering Notebook to see how you defined the problem throughout solving the problem. How has your understanding of the problem changed during the design process? Think in terms of client needs, criteria, constraints, and the science and mathematics needed to solve the problem.*
  My response:
  Team response:
- *Look back in your Engineering Notebook to see how you developed your solution throughout solving the problem. How has your understanding of how to design a solution changed during the design process? Think in terms of what you did and how you made decisions to solve the problem.*
  My response:
  Team response:
- *How do engineers solve problems?*
  My response:
  Team response:

Assessments

Pre-Activity Assessment
Students brainstorm different ways that engineers communicate to their client.

Activity Embedded Assessment
Turn and talk with your design team, "*What is the criteria that client wants you to meet for your final design?*" Your communication with the rationale for your design choices is due at the end of this class (remind the students that is a constraint).
Evidence-Based Reasoning Solution- Graphic (8.a)
Decide Questions in Engineering Notebook (8.b)

Post-Activity Assessment
Students turn in their communication.

Students answer Decide Questions in Engineering Notebook.

DUPLICATION MASTERS

- 8.a. Evidence-Based Reasoning - Solution Graphic
- 8.b. Final Communication to the Client Rubric
- 8.c. Science Assessment
- 8.d. Engineering Notebook Reflection Questions

EDUCATOR RESOURCES

- none

LESSON 8

Name______________________________ Date__________ Period _____

8.a. Evidence-Based Reasoning - Solution Graphic

Problem with Criteria & Constraints (What do you need to worry about?)

Problem: ______________________________

____

Criteria: ______________________________

Constraints: ______________________________

Simplifying Assumptions (What do you not need to worry about?)

____

____

Plan (Design Idea)	**Data/Evidence** (Facts)

Explanation, Justification, Reasoning (Why do you think this will work?)

____

____

____

____

____

____

____

LESSON 8

Name_______________________ Date___________ Period _____

8.b. Final Communication to the Client Rubric

	3	2	1
Drawings and description of your design	Draws designs, labels parts, and describes designs using as many details as possible	Draws and describes a picture of the design with some detail	Draws designs and describes them with little detail
Explanation of how your model meets client's needs	Explains how the design meets the client's needs	Describes how most of the needs of the client will be met	Little or no description of how the needs of the client will be met
Appropriate use/application of science and math content	Uses several evidences from previous investigations (observations, experimental findings etc)	Uses few evidences from previous investigations	Do not use any evidences from previous investigations
Clarity, completeness, and accuracy	Uses accurate, relevant, and significant vocabulary words	Some vocabulary words are included in the communication	Few of the vocabulary words are included in the communication

LESSON 8

Name________________________________ Date____________ Period ______

8.c. Science Assessment

1. **A student is growing many types of fruits and vegetables in her garden. Which factors affect the growth of the plants?**
A. Water and soil.
B. Soil and sunlight
C. Water and sunlight.
D. Water, soil and sunlight.

2. **There is a tree growing in the middle of a sunflower field. What will happen to sunflowers as the tree's leafy branches block out more and more sunlight?**
A. Grow as large as the tree to compete for sunlight.
B. Learn to live without sunlight.
C. Climb up the tree and live on its branches.
D. Begin to grow more slowly.

3. **Students are participating in a project to investigate the effect of water on the growth of tomatoes. Tomato plants will be grown in a greenhouse and height of plants will be measured each week. Which of the following strategies is the most important in this project?**
A. Using proper materials to accurately measure plant growth.
B. Using different amount of water for each plant pot.
C. Placing plant pots in different places in the greenhouse.
D. Using a different type of soil in each plant pot.

4. **Which one of the following materials help keeping things warm?**
A. Aluminum foil
B. Wool sock
C. Saran wrap
D. Paper towel

5. **Resources such as water and sunlight are likely to be limiting factors when?**
A. Plants need to share resources with other plants
B. Plants are healthy
C. Plants planted in large pots
D. Plants grow slowly

6. **Which kind of plant survives in a desert?**
A. A plant with purple leaves
B. A plant with the largest leaves
C. A plant with a small root system
D. A plant with the largest root system

7. **Students want to find out how the amount of light a plant receives affects the mass of the plant. They set up 3 pots, each with a tomato plant. The first plant receieves 8 hours of light per day and the second receives 12 hours of light per day, and the third receives 18 hours of light per day. What is the variable controled in this experiement?**
A. Hours of light per day the plants receive
B. The number of plants per pot
C. The type of plant
D. All the above

8. **Which part of a flowering plant absorbs water and minerals?**
A. Flower
B. Stem
C. Root
D. Blade

9. **What are a flower's female reproductive parts called?**
A. Sepals
B. Anthers
C. Pistils
D. Filaments

10. **What part of a flowering plant becomes fruit?**
A. Ovary
B. Stamen
C. Petal
D. Pistil

LESSON 8

Name________________________________ Date___________ Period _____

8.d. Engineering Notebook Reflection

First, **on your own**, answer each of the following questions beside the "My Response" space. Then, in your teams, each person is to share their response and discuss. In the space, "Team Response" write your revised answer to the question, based on discussion with your team. You may use a different color writing utensil to distinguish your answer and how it changed after talking with teammates.

1. **Look back in your Engineering Notebook to see how you defined the problem throughout solving the problem. How has your understanding of the problem changed during the design process? Think in terms of client needs, criteria, constraints, and the science and mathematics needed to solve the problem.**
   My response:

   Team response:

2. **Look back in your Engineering Notebook to see how you developed your solution throughout solving the problem. How has your understanding of how to design a solution changed during the design process? Think in terms of what you did and how you made decisions to solve the problem.** My response:

   Team response:

3. **How do engineers solve problems?**
   My response:

   Team response:

Notebook Prompts and Titles

Teacher Directions:

If you prefer to have students write the answers to prompts right in their notebooks (rather than on the handouts and then adhere them to the notebooks), you should have the students put the bold title for each prompt and then answer the question that follows. The format for each will be as follows:

> **Prompt title:**
> Question to answer

Have students answer each set of questions as they appear in the curriculum. If any questions are included in the curriculum, but not included here, you may determine the title for the prompt.

Problem Scoping Lessons - Define and Learn

Section 1:

Engineers:
What do engineers do?

Solve Problems:
How do engineers solve problems?

Section 2:

Questions for client:
What questions do you want to ask to the client?

Section 3:

Client:
Who is the client?

Problem:
What is the client's problem that needs a solution?

Why it is important:
Why is the problem important to solve?

End-users:
Who are the end-users?

Criteria:
What will make the solution effective (criteria)?

Notebook Prompts and Titles

Constraints:
What will limit how you can solve the problem (constraints)?

What we need to learn:
Think about the problem of greenhouse design. In terms of designing a greenhouse to extend the growing season of tomatoes, what do you need to learn in order to create a successful design?

Generate Ideas/Plan Lessons

Section 1:
EBR Graphics can just be drawn in notebooks.

Section 2:
Have students answer the following after EBR graphics are complete.

Pros and Cons:
What are the pros and cons of each of your solutions?

Why we chose our solution:
Which solution did your team choose and why?

Test Solution Idea(s) Lessons

Section 1:
Ask students to complete after they have run their tests.

Learned from test results:
What have you learned about the performance of your solution from your test results?

Changes from test results:
What changes will you make to your solution based on the results of your tests? Explain why you want to make those changes.

Changes from science/math learned:
What improvements will you make to your solution based on the science and/or math you have learned? Explain why you want to make those changes.

Notebook Prompts and Titles

Section 2:

Section 2 questions should come after the students have run their tests and have had an opportunity to answer Section 1 questions.

How solution meets criteria and constraints:
In what ways does your solution meet the criteria and constraints of the problem?

How solution does not yet meet criteria and constraints:
In what ways does your solution not yet meet the criteria and constraints of the problem?

Changed problem description:
Go back and look at how you described the problem right after talking with the client. How would you change your description of the problem now that you have planned, tried, and tested a solution? (Think about criteria, constraints, client need, and/or things you need to learn.)

Decide/Final Solution Lessons

Section 1:

Students use evidence-based reasoning in reporting their final solution to the client. This can happen through use of the EBR graphic as part of their memo or presentation, or you can have the students include the aspects of the EBR graphic (without the graphic itself) in the memo or the presentation.

Section 2:

These questions should be completed after presenting the solution to the client and the entire design challenge is complete.

Understanding of the problem:
Look back in your Engineering Notebook to see how you defined the problem throughout solving the problem. *How has your understanding of the problem changed during the design process?* Think in terms of client needs, criteria, constraints, and the science and mathematics needed to solve the problem.

Understanding of designing a solution:
Look back in your Engineering Notebook to see how you developed your solution throughout solving the problem. *How has your understanding of how to design a solution changed during the design process?* Think in terms of what you did and how you made decisions to solve the problem.