CSI: Carbon Sink Investigation

High School Biology

SCALE K-12
SCalable Asymmetric Lifecycle Engagement
Precollege Microelectronics Workforce Development

INSPIRE
Research Institute for Pre-College Engineering

PURDUE
UNIVERSITY

Cover Information

Unit Title: CSI: Carbon Sink Investigation
Grade Level Range: High School Biology

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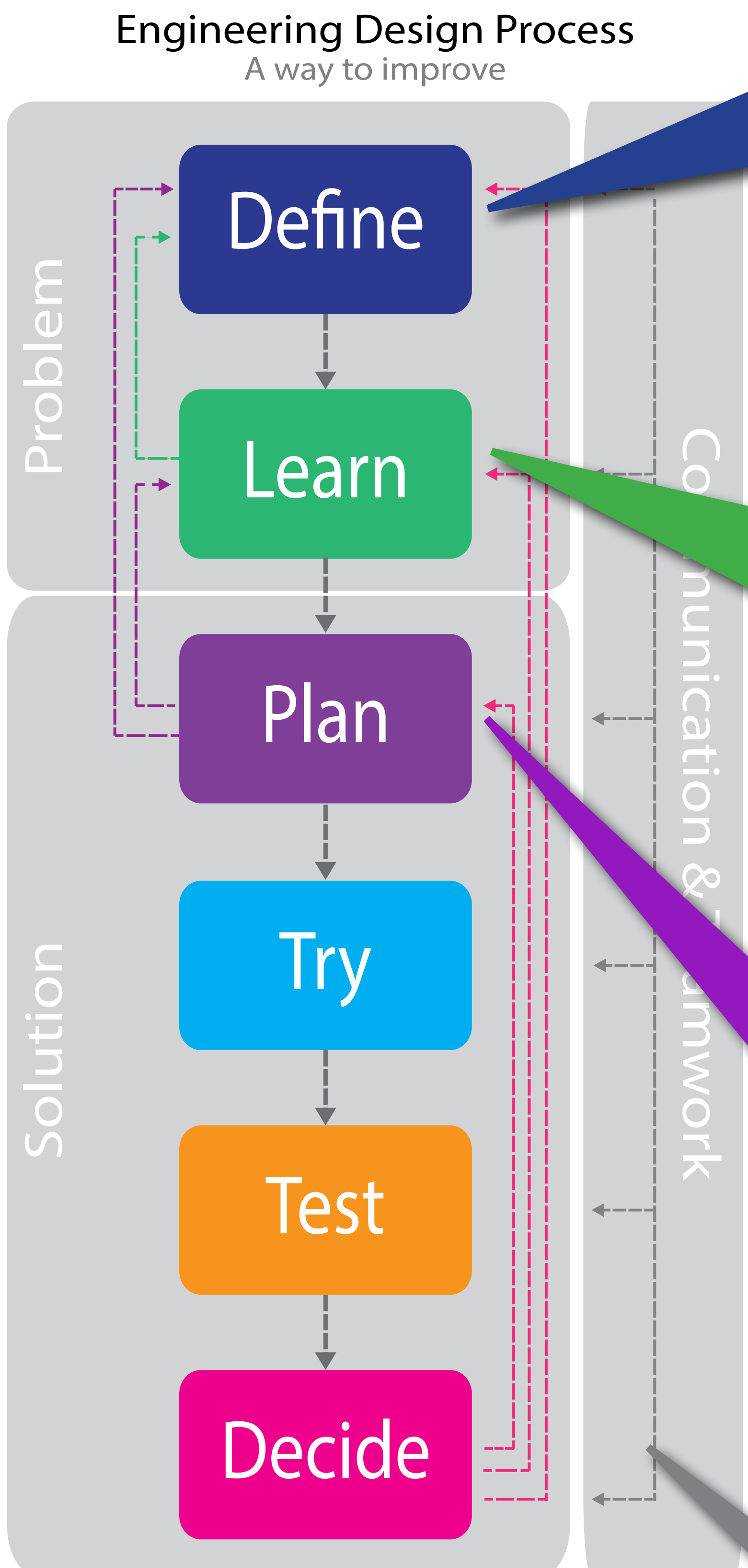


DEFINE THE PROBLEM

- Who is the **client**?
- What does the client need?
- Why does the client need it?
- Who is the **end user**?
- Why might the end user want it?
- What are the **criteria** (requirements)and **constraints** (limits) of the solution?

Problem Scoping:
WHO needs **WHAT** because **WHY**

LEARN ABOUT THE PROBLEM

- What kind of background knowledge is needed?
  - What science/math 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 success and improvement?

PLAN A SOLUTION

- Continue to specify the criteria/ constraints
- Generate ideas of possible solutions
- Develop multiple solution paths
- Consider **constraints, criteria**, and **trade-offs** (criteria that compete with one another)
- Choose a solution to try
- Develop plans (blueprints, schematics, cost sheets, storyboards, notebook pages, etc.)

COMMUNICATION

- Communicate the solution clearly and make sure it is easily understandable
- Use **evidence** to support why the client should use your solution

TRY A SOLUTION

- Put the plan into action
- Consider risks and how to optimize work
- Use criteria/constraints and consider trade-offs from the 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 determine if the solution is meeting the stated criteria, constraints, and needs
- Collect and analyze data

DECIDE IF THE SOLUTION IS GOOD ENOUGH

- Are users able to use the design to help with the problem?
- Does the design meet the criteria and constraints?
- How could the design be improved based on test results and feedback from the client/user?

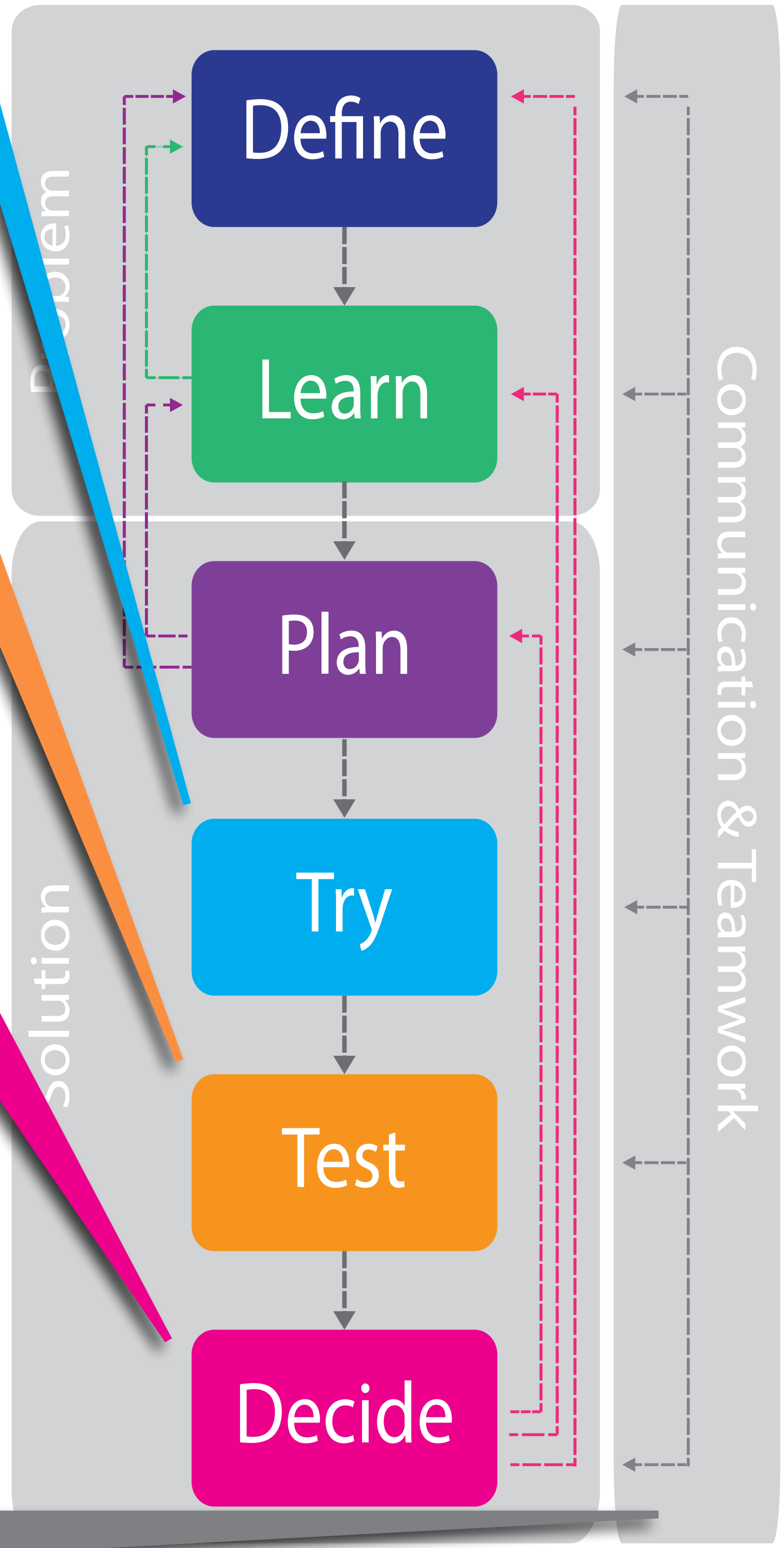
Iterative nature of design: Always consider which step should be next!

TEAMWORK

- Discuss in teams how the solution meets the criteria and needs of the client
- Consider different viewpoints from each teammate

Engineering Design Process

A way to improve



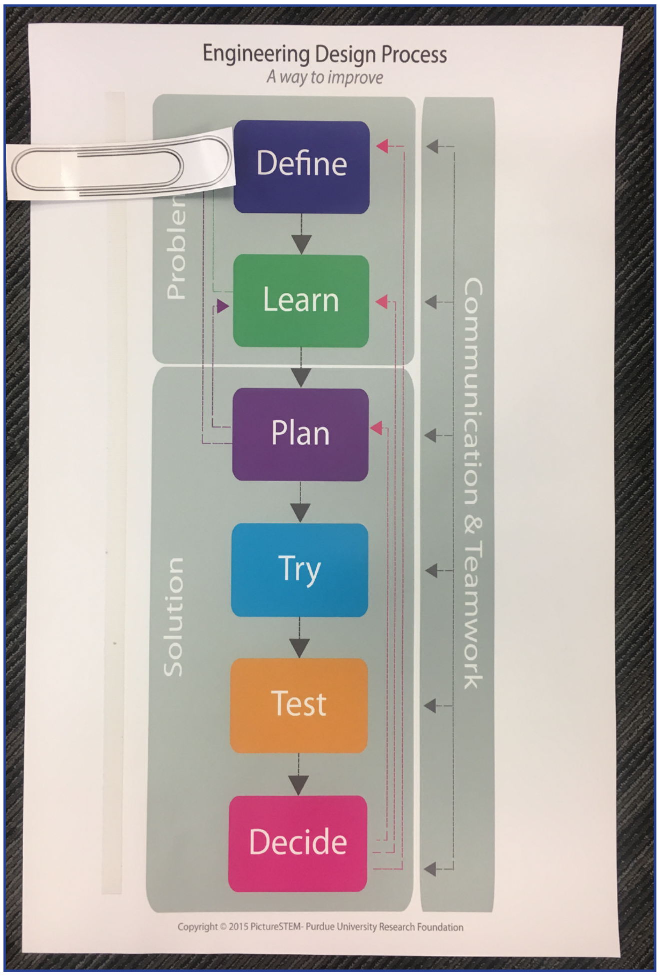
Overview: How to make EDP sliders

How to create the poster

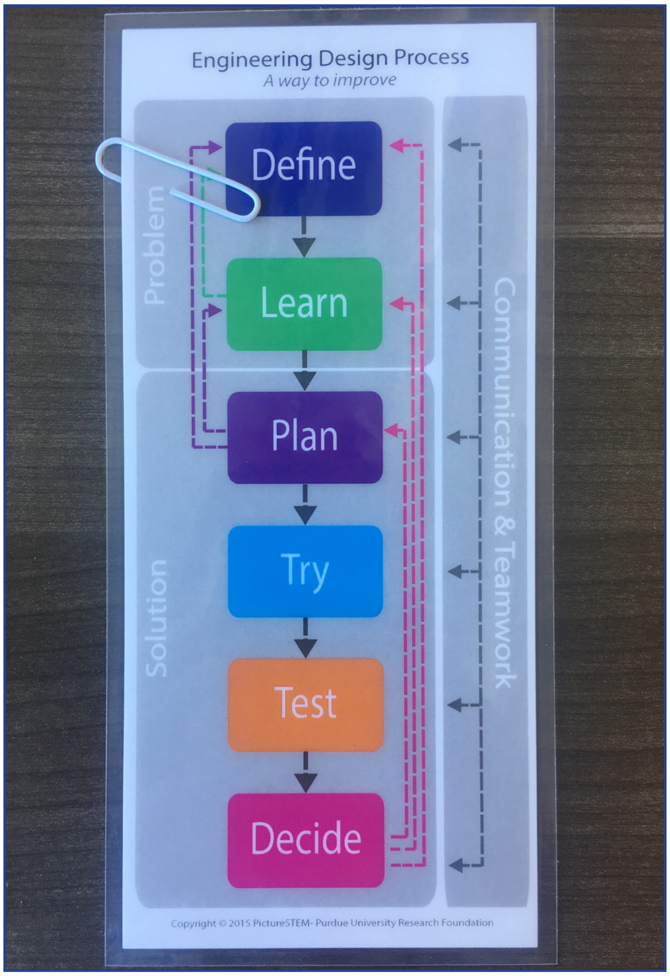
1. Download the high-quality PictureSTEM Slider Poster and the paper clip images from PictureSTEM.org.
2. Print the poster and the paper clip on poster-sized paper and cut to size. High-gloss or semi-gloss paper is the best choice.
3. Use self-sticking Velcro on the back of the paper clip and down the side of the poster so that the paper clip can be placed to point at all 6 sections of the slider.

How to create individual sliders

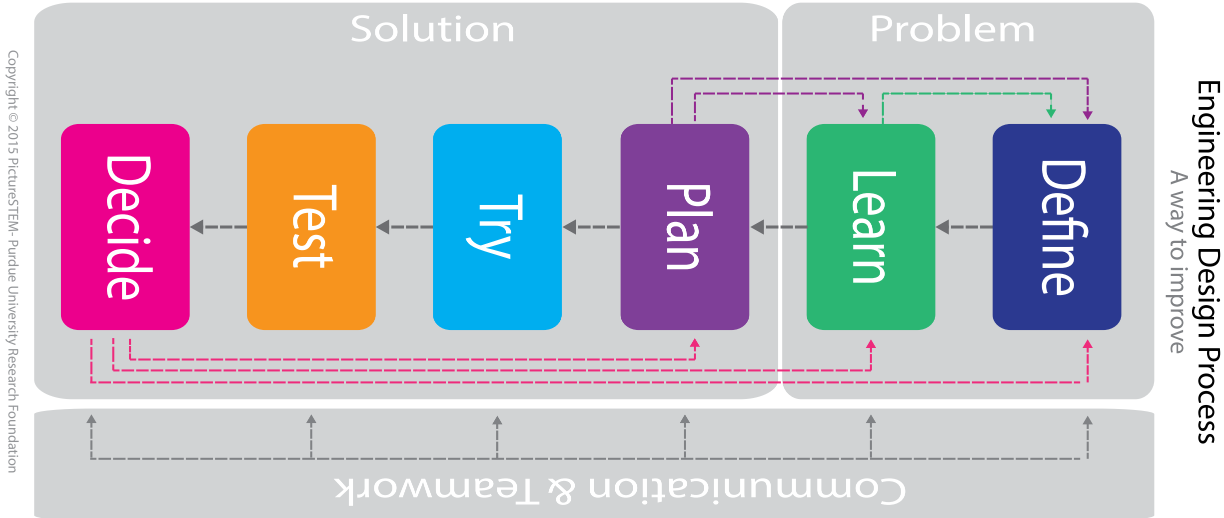
1. Print the sliders on the opposite page - enough for one slider per student in your class.
2. Cut the sliders apart.
3. Laminate the sliders individually.
4. Use a jumbo paper clip as the pointer for each slider.



Poster



Individual slider


Engineering Design Process
A way to improve
Problem
Solution
Define
Learn
Plan
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Communication & Teamwork
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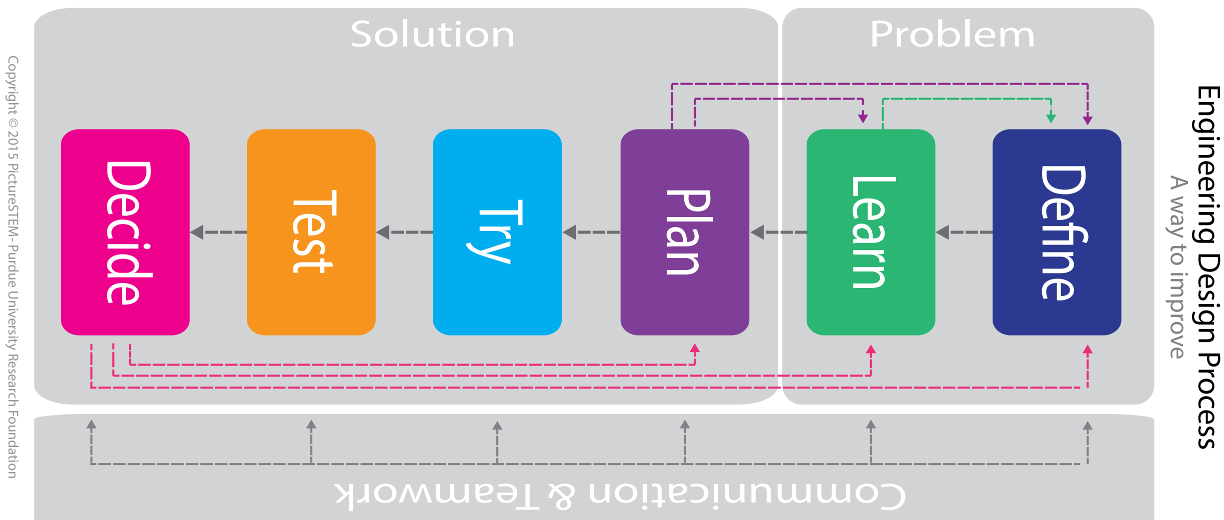
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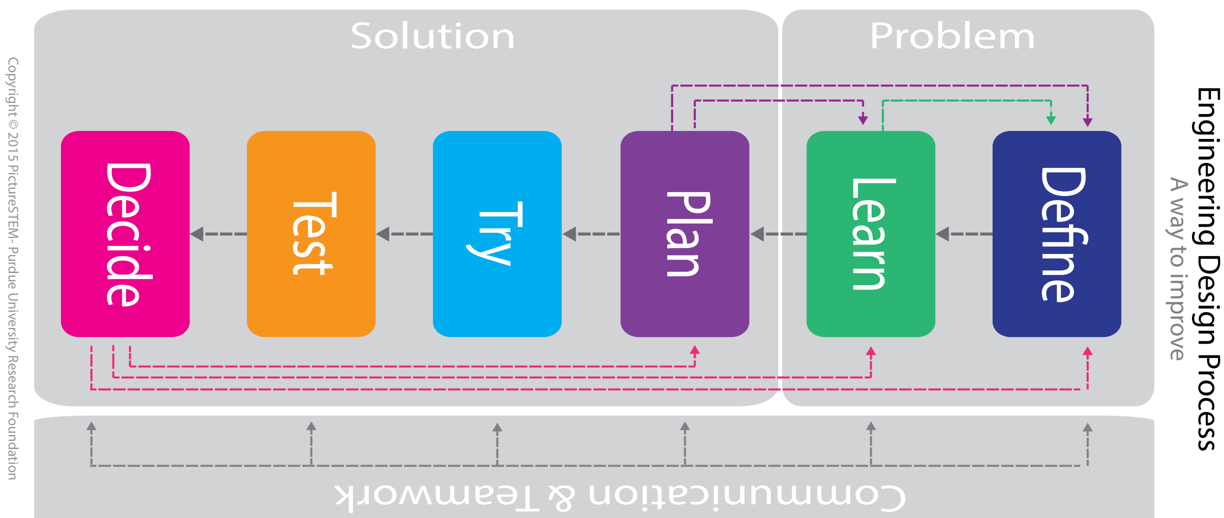
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Unit Overview

Grade Levels: High School Biology

Approximate Time Needed to Complete Unit: 3 weeks

Unit Summary

In this unit, a client asks students to engage in an engineering design challenge of reducing the effect of carbon emissions from a nearby power plant. Students are tasked with creating a carbon sink. Lessons are provided about the carbon cycle, climate and environmental justice, microelectronic sensors, photosynthesis, and cellular respiration. Students will brainstorm their ideas, build an algae farm, and test it to see how effective they were at reducing atmospheric carbon.

Subject Connections

Science Connections	Technology and Engineering Connections	Mathematics Connections
Algae, carbon, carbon cycle, carbon sink, cellular respiration, fossil fuels, photosynthesis	Engineering design challenge, engineering design process, environmental justice, evidence-based reasoning, microelectronics, sensors	Beer's Law, solving equations

Standards

Next Generation Science Standards

HS-ETS1-1 Engineering Design

Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

HS-LS2-5 Ecosystems: Interactions, Energy, and Dynamics

Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.

LS2.B Cycles of Matter and Energy Transfer in Ecosystems: Photosynthesis and cellular respiration are important components of the carbon cycle, in which carbon is exchanged among the biosphere, atmosphere, oceans, and geosphere through chemical, physical, geological, and biological processes.

2-LS2-1 Ecosystems: Interactions, Energy, and Dynamics

LS2.A interdependent Relationships in Ecosystems: Plants depend on water and light to grow.

Lesson Summaries

Lesson 1: Intro to Design Challenge
Students are introduced to the engineering challenge by their client which will serve as the context within which students can learn about photosynthesis and cellular respiration. Students will learn about the Engineering Design Process and take part in iterative class and group discussions to identify criteria, constraints, and knowledge gaps needed to successfully solve the client's challenge.

Lesson 2: The Carbon Cycle
The carbon cycle is an important concept to learn as students will be attempting to reduce the concentration of carbon emitted into the atmosphere. After briefly reviewing the carbon cycle, students will play a dice game where each student acts as a carbon molecule moving through the cycle. The lesson will conclude with a review of why it is important to reduce carbon emissions.

Lesson 3: Microelectronic Sensors
An important part of this engineering design challenge involves measuring atmospheric CO2. In this lesson, students will learn why having an accurate measure of CO2 is important to combating climate change. They will also learn how a sensor can accurately measure this gas, and why each component is important.

Lesson 4: Carbon and the Environment
Students will learn the definitions of climate justice and environmental justice. After discussing how this relates to their engineering design challenge, students will read a new client memo. This memo asks students to research methods of carbon sequestration that can alleviate environmental and social injustice.

Lesson 5: Photosynthesis
Students will learn about photosynthesis and cellular respiration through a lab that demonstrates the two processes. After reviewing the equation that converts light energy into chemical energy, students will work together in groups on the lab.

Lesson 6: Cellular Respiration
Students will learn about cellular respiration and the equation components. After reviewing that glucose and oxygen are vital for cellular respiration to occur, students will work through lab questions in groups.

Lesson 7: Carbon Sink Brainstorming
Now that students have learned about fossil fuels, the carbon cycle, cellular respiration, photosynthesis, and sensors, they are ready to develop their ideas into a solution to the engineering design challenge. Students will work individually and in teams to brainstorm different algae configurations. Using evidence-based reasoning, they will make a decision as a team.

Lesson 8: Carbon Sink Model Creation
In this lesson, students will build their algae farms based on the standard operating procedure they wrote in the previous lesson. The atmospheric carbon concentration of the classroom will be measured as a baseline. Students will make observations about the visual appearance of their algae farm.

Lesson 9: Data Collection
Students will measure the atmospheric carbon levels within their algae farms to determine if it has successfully reduced over time. Design teams will then critically think about their design and decide what its pros and cons are.

Lesson 10: Design Review and Implications
In this lesson, students will report out their group findings to provide a holistic, evidence-based recommendation to the client as a class. Students will prepare presentations as a team to share their design with the class. Students will review one another using the decision matrix prior to providing a final recommendation to the client.

Unit Planner

Lesson	Time Needed	Objectives	Duplication Master
1. Engineering Design Challenge	100 minutes	• Identify the problem from a client • Explain the differences and similarities between the engineering design process and scientific inquiry • Identify background knowledge needed to develop a solution • Explain the criteria and constraints of this engineering design challenge	1.A Content Pre-Assessment 1.B Problem Scoping Prompts 1.C EDP and Scientific Inquiry Comparison 1.D Client Letter
2. The Carbon Cycle	50 minutes	• Explain each step of the carbon cycle • Identify the relationship between the carbon cycle, photosynthesis, and cellular respiration • Explain the impact of carbon emissions	2.A Client Memo 1 2.B Activity 1 – Human Control 2.C Activity 2 – Sphero Draw 2.D Activity 3 – Sphero Draw Challenge 2.E Activity 4 – Sphero Block Coding 2.F Sphero Evaluation Sheet
3. Microelectronic Sensors	50 minutes	• Explain why it is important to keep track of atmospheric carbon emissions • Explain how an atmospheric carbon sensor works • Define the term, “microelectronics”	3.A Atmospheric CO2 Sensor Diagram 3.B Beer-Lambert Law Worksheet
4. Carbon and the Environment	50 minutes	• Define environmental justice • Define climate justice • Make connections between environmental justice and climate change • Discuss one method of carbon sequestration that can alleviate injustice	4.A Client Memo 2 4.B Paragraph Requirements
5. Photosynthesis	50 minutes	• Identify the reactants and products of photosynthesis • Explain the importance of photosynthesis to the carbon cycle • Understand the basic process involved in photosynthesis • Identify factors that affect the rate of photosynthesis	5.A Photosynthesis and Cellular Respiration Lab 5.B Data Collection Table

Lesson	Time Needed	Objectives	Duplication Master
6. Cellular Respiration	50 minutes	• Identify the relationship between photosynthesis and cellular respiration • Identify the reactants and products of cellular respiration • Understand the importance of cellular respiration to the carbon cycle • Identify factors that affect the rate of cellular respiration • Explain the transfer of energy occurring within the process	6.A Lab Discussion
7. Carbon Sink Brainstorming	50 minutes	• Design solutions to an engineering design challenge • Use evidence-based reasoning while designing a solution to a problem • Write a standard operating procedure	7.A Client Memo 3 7.B Algae Strain Information 7.C Evidence-Based Reasoning 7.D Standard Operating Procedure
8. Carbon Sink Model Creation	50 minutes	• Build an algae farm • Measure atmospheric carbon	8.A Data and Observations
9. Data Collection	50 minutes	• Collect atmospheric carbon data	9.A Data and Observation
10. Design Review and Implications	100 minutes	• Communicate science, technology, engineering, and mathematics ideas through presentations • Use evidence-based reasoning to support their engineering decisions	10.A Client Memo 4 10.B Client Communication Requirements 10.C Decision Matrix Directions 10.D Decision Matrix Activity 10.E Client Memo 5 10.F Content Post-Assessment

Master Materials List

	Unit Materials	Lessons Where Material is Used
Per Classroom	EDP Poster Chart Paper Label tape Bromthymol blue solution Vernier CO_2 Gas Sensor Vernier LabQuest 3	1, 2, 3, 4, 5, 6, 7, 8, 9, 10 1 5 5 8, 9 8, 9
Per Group (assume 3 students per group)	Two 125-mL flasks 2 rubber stoppers for 125-mL flasks Marker 100-mL graduated cylinder Drinking straw 2 sprigs of Elodea Plastic divider bin with attached lid and dividers Filtered water (must be free from chlorine) Salt Algae strains Constructed algae farm	5 5 5 5 5 5 8 8 8 8 9
Per Student	EDP slider and paperclip Laptop/Chromebook/Tablet Engineering notebook Pencils and erasers 1 die Latex gloves Safety glasses	1, 2, 3, 4, 5, 6, 7, 8, 9, 10 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 2 5, 8, 9 5, 8, 9

LESSON ONE:

Lesson Summary

Students are introduced to the Engineering Challenge by their client which will serve as the context within which students can learn about photosynthesis and cellular respiration. Students will learn about the Engineering Design Process and take part in iterative class and group discussions to identify criteria, constraints, and knowledge gaps needed to successfully solve the client's challenge.

Background

Teacher Background

Teamwork: Students should be teamed strategically and may or may not be assigned jobs within their team. When forming student teams, consider academic, language, and social needs. In place of strategic teaming, a random teaming can be substituted. Students will work in these teams of 3 or 4 throughout the unit. Effective teamwork is essential in this unit as well as in engineering in general. The teams will operate as consulting engineers with each team specializing in a specific measuring device eventually working together as a class to address the client's problem.

Career Connections: Students will be introduced to new STEM content potentially for the first time. There are many career opportunities that align with the content in this unit. Please plan to highlight these as you see fit and encourage students to think about how these topics align with their personal and future interests.

Engineering Design Process:
NOTE: If students are familiar with the engineering design process (EDP) before beginning the unit, the teacher can skip this (EDP) introduction.

The engineering design process (EDP) is an iterative, systematic process used to guide the development of solutions to engineering problems. There is no single engineering design process, just like there is no one scientific method. However, the various engineering design processes have similar components. The engineering design process (EDP) involves understanding the problem, learning background information necessary to solve the problem, planning, trying, testing the solution, making changes based on the tests, and communicating their ideas. Students will use an engineering design process slider throughout the unit to help them understand where they are in the design process. For more information about the steps of the engineering design process presented in this unit, see

Lesson Objectives
Students will be able to:
- Identify the problem from a client.
- Explain the differences and similarities between the engineering design process and scientific inquiry.
- Identify background knowledge needed to develop a solution.
- Explain the criteria and constraints of this engineering design challenge

Time Required
Two 50-minute lessons

Materials
Per classroom
- EDP Poster
- Chart paper

Per student
- EDP slider and paperclip
- Laptop/Chromebook/Tablet
- Engineering notebook
- Pencils and erasers

Standards Addressed
- NGSS: HS-ETS1-1

Key Terms
Client, engineering design process, criteria, constraints, microelectronics

the front matter section about it.

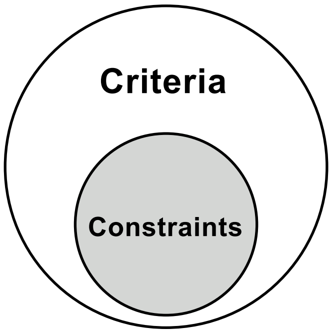
Some common misconceptions about engineering:

- Engineers do not have to learn anything new when they are working on a project. **In reality:** Engineers need to continually learn throughout their lives.
- Engineers come up with solutions that are just "good enough" and do not take risks. **In reality:** Engineers strive to create the best solution possible through optimization. It is normal to experience failure when solving engineering problems.
- Engineers work alone to solve a design problem. **In reality:** Engineers collaborate with people in different disciplines and fields to best solve a problem. Engineering problems often require a wide range of content knowledge.

Some common misconceptions about the EDP:

- The engineering design process is linear, and you never need to go back to previous phases. **In reality:** The EDP is a cyclical process that requires many iterations.
- Once the project is done, it is considered complete and not revisited. **In reality:** The engineering design process is never really "done" and it is revisited so engineers can improve projects and make changes.

Criteria and Constraints: One difficulty that students might experience is distinguishing between criteria and constraints. Criteria are the things required for a successful design, or goals of the designed solutions. They help engineers decide whether the solution has solved the problem. Another way of thinking about criteria are that they are anything that the client and the engineers will use to judge the quality of a solution. Constraints are a specific type of criteria; they are those criteria that limit design possibilities, or the ways that that problem can be solved. If constraints are not met, the design solution is by default not a viable solution to the problem. The relationship between criteria and constraints is represented in the figure. It may be helpful to post the definitions with the figure somewhere in the classroom for future reference.



Duplication Masters
1.A Content Pre-Assessment
1.B Problem Scoping Prompts
1.C EDP and Scientific Inquiry Comparison
1.D Client Letter

Educator Resources
1.E Content Pre-Assessment Key
1.F Problem Scoping Section 3 Key

Assessment

Pre-Activity Assessment:
Assess students' prior knowledge by listening to their responses to 1.B Problem Scoping Prompts. Use students' answers to 1.A Content Pre-Assessment as baseline data about the students' current level of understanding and background knowledge.

Activity Embedded Assessment:
Observe students' discussions and written responses to 1.B Problem Scoping Prompts. Check students' brainstorming lists to see if they can identify the content they will be expected to master by the end of the unit.

Post-Activity Assessment:
Use 1.E Content Pre-Assessment Key and 1.F Problem Scoping Section 3 Key to evaluate students' answers to the notebook prompts and content questions.

Problem Scoping: In this lesson, students will be in the Problem Scoping section of the engineering design process, specifically on the define the problem step. Define the problem and learn about the problem combine to make Problem Scoping. In this stage, students will be first introduced to the engineering problem through a client letter and then be given a chance to ask questions to the client to receive more information about the problem. The problem statements given in the client memos purposefully do not provide all the information necessary to solve the problem. Students are tasked with generating questions about the problem to try to fill in this missing information. Based on all information from the client, students will then define the problem in terms of: what the problem is and why it is important, who are the client and end users, what are the criteria and constraints, and what other information they may need to learn about in order to solve the problem. This process of generating ideas and questions for the client is an important skill on its own both in engineering and in other fields, but it also helps to ensure that the students fully understand the problem and their task in the engineering design challenge.

Solution Generation: The Solution Generation section of the engineering design process includes plan the solution, try out the plan of the solution, test the solution, and decide whether the solution is good enough. When engineers are generating solutions, they will use iteration as a means to continually improve their solution, reflect back on the problem definition and what they have learned about the problem, and consider criteria, constraints, and trade-offs. Trade-offs involve having to make compromises about which criteria to emphasize because they compete with one another in terms of making the solution effective. For example, cost could be a trade-off for durability.

Engineering Notebook: Throughout the unit students will be recording information in an engineering notebook, and they will need the notebook immediately in Lesson 1. The engineering notebook is a set of documents which includes writing prompts, black space to take notes or add pictures of work, and copies of the duplication masters that are listed in each lesson. The engineering notebook can be offered as a google doc if this better fits your classroom needs. Students' engineering notebooks will support their communication of ideas and should be used consistently throughout the unit.

Vocabulary: Students will be introduced to many new science and engineering vocabulary terms throughout the unit. It may be helpful to create a vocabulary section in their notebook with term definition and memory clue. Additionally, the class could maintain a word wall.

Teacher Background

- Assemble the Engineering Design Process Sliders and post the EDP poster in the classroom (see the front matter for how to assemble them). If your students do not want to use the sliders, simply hanging the poster achieves the same result. Make sure you and your students can refer to the EDP sliders and/or poster throughout the unit.
- Determine student teams of three or four. These teams should be their teams throughout the rest of the unit.
- Print and make copies of the following worksheets in the labeled amounts:
    - (1 per student) 1.A Content Pre-Assessment, 1.D Client Letter
    - (1 per group) 1.C EDP and Scientific Inquiry

Classroom Instruction

Introduction

1. **Complete the pre-assessment activity.** The students will participate in a more formal pre-assessment to assess their current level of knowledge and understanding regarding the topics of fossil fuels, the carbon cycle, photosynthesis, cellular respiration, microelectronics, and the engineering design process. Distribute hard copies of Duplication Master 1.A Content Pre-Assessment. Make sure to tell students that this is just to assess any prior knowledge, so it is okay to not know all the correct answers.
2. **Review prior knowledge.** Lead a discussion with the class in which students are able to share their prior knowledge on the topics of engineering, photosynthesis, cellular respiration, and electronics. Prompts may include the following: *What do engineers do? What kinds of industries do engineers work in? What happens in photosynthesis? How does cellular respiration occur? What do sensors do?*
3. **Engineering notebooks. Say:** *Engineers use notebooks to document their design process and keep notes. We will also be using Engineering Notebooks throughout our engineering challenge. Each day, you'll use the engineering notebooks to take notes and record what you are learning. In addition, there are questions that you'll be asked to answer.* NOTE: You can have your students type in their notebooks in two different

colors – one for thoughts and prompts that are individual and one for thoughts and prompts that they discuss in their teams. This will help both you assess, and the students recognize, where ideas came from. You also may want to have students start a Table of Contents page.

4. **Complete problem scoping section 1.** Direct students to the 1.B Problem Scoping Prompts in their engineering notebooks. Have students individually answer the prompts from section 1. Make sure to let them know that it is okay if they do not know very much about engineers or engineering – just have them answer these questions to the best of their ability.
5. **Form teams.** After students have finished the prompts, explain that for the rest of the unit they will start the day with a review of the engineering design process, and then look at a specific problem that will require the use of that process. Explain that students will be working in small teams to solve a problem being brought to them by the client. Divide students into teams of 3 or 4.

Activity

6. **Discuss engineers and engineering.** Allow students to share their answers from 1.B Problem Scoping Prompts section 1. Define engineers and engineering and take some notes for students to share in their engineering notebooks. As a class create a list of the different types of engineering and have students brainstorm careers that may fall within each type of engineering in their notebooks. Explain that the problem they will be solving falls under the category of environmental engineering and draws on biology and electronics to understand the context and generate a solution.
7. **Introduce the Engineering Design Process.** Display the Engineering Design Process poster and pass out individual EDP Sliders and a paper clip to each student. **Say:** *Engineers use an engineering design process, along with mathematics, science, and creativity, to understand a problem and come up with a solution. Since we are working as engineers during this unit, we will be using this engineering design process as a guide while we come up with a solution for our engineering problem.* Go through the EDP Slider and ask the students what they think each stage involves. Be sure to clarify any misconceptions and elaborate where needed. There is a detailed description of the EDP Slider in the front matter of the unit. **Ask:** *Based on what we have discussed so far, where do you think we are in the engineering design process?* **(Define).**
8. **Compare the Engineering Design Process and Scientific**

Inquiry. Have students individually examine 1.C EDP and Scientific Inquiry Comparison then, in their groups, discuss the differences and similarities between the two methods. Remind them to keep track of the discussion in their engineering notebooks to share back with the class later. Have a class discussion allowing groups share what they noticed about the two methods.

NOTE: If you don't have time, you can skip comparing the two processes.

9. **Introduce the problem.** Allow students time to read copies of the 1.D Client Letter. Encourage them to type in their notebooks as they read to keep track of important information. Give students time to discuss in small teams what information they read in the letter. **Ask:** *What is the challenge? What are some possible constraints and criteria?*
10. **Identify the problem from the client.** Have the students reread the letter, if necessary, to identify the problem and type it in their notebooks.
11. **Identify required information.** Have students work together to brainstorm a list of "required information" in order to help the client with their request. Encourage them to highlight/underline the things on their list they already know. Then as a class create an anchor chart that will be revisited throughout the unit. As students learn information you can check content off of the anchor chart or add to it if they think of some other information that they will need to help the client.
12. **Complete problem scoping section 2.** After reading the letter, direct students to respond to section 2 of the 1.B Problem Scoping Prompts in their engineering notebooks. They can do this individually or in teams.
13. **Complete problem scoping section 3.** After students have completed the section 2 prompt, direct students to section 3 of 1.B Problem Scoping Prompts. They can do this individually or in teams.

Closure

14. **Revisit the problem.** Give the students a chance to revise their list of questions or required information they composed for the engineering challenge.
15. **Discuss the engineering design process. Ask:** *Which phase of the engineering design process did we focus on related to our challenge today? Why is this important?* Ex: Students need to understand the root problem from the perspective of the client and other stakeholders before attempting a solution.

Name______________________________________ Date______________ Period __________

1.A Content Pre-Assessment

1. List five steps of the carbon cycle.

2. How does a microelectronic sensor measure atmospheric carbon?

3. What is environmental justice?

4. How do carbon emissions negatively impact the environment?

5. Explain what happens during photosynthesis. Write the chemical equation for photosynthesis.

6. Explain cellular respiration and its purpose.

7. What does the term, "microelectronics" mean?

8. How are microelectronics used in the field of biology?

9. What jobs would you be interested in that use microelectronics?

10. Provide one example of how microelectronics is used in that job.

Name____ Date_______________ Period __________

1.B Problem Scoping Prompts

Section 1:
Directions: Please answer the following questions.

1. What do engineers do?

2. How do engineers solve problems?

Section 2:
Directions: Please answer the question after hearing about the engineering design challenge.

3. What questions do you want to ask the client?

Name____ Date_______________ Period __________

1.B Problem Scoping Prompts

Section 3:

Directions: Please answer these questions after you have been able to ask questions about the challenge. First, complete each prompt on your own. Then write your revised answer (if different) to the prompt, based on the discussion with your team. You may use a different color writing utensil to distinguish your answer and how it changed after talking with teammates.

4. The client is:

5. The client's problem is:

6. The problem is important to solve because:

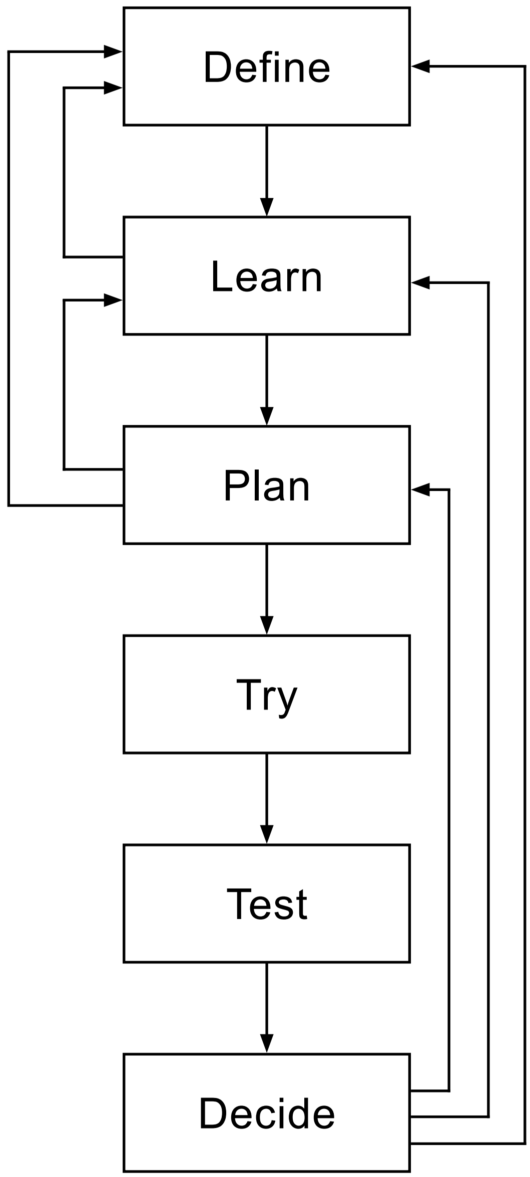
7. The end-users are:

8. An effective solution for the client will meet the following criteria:

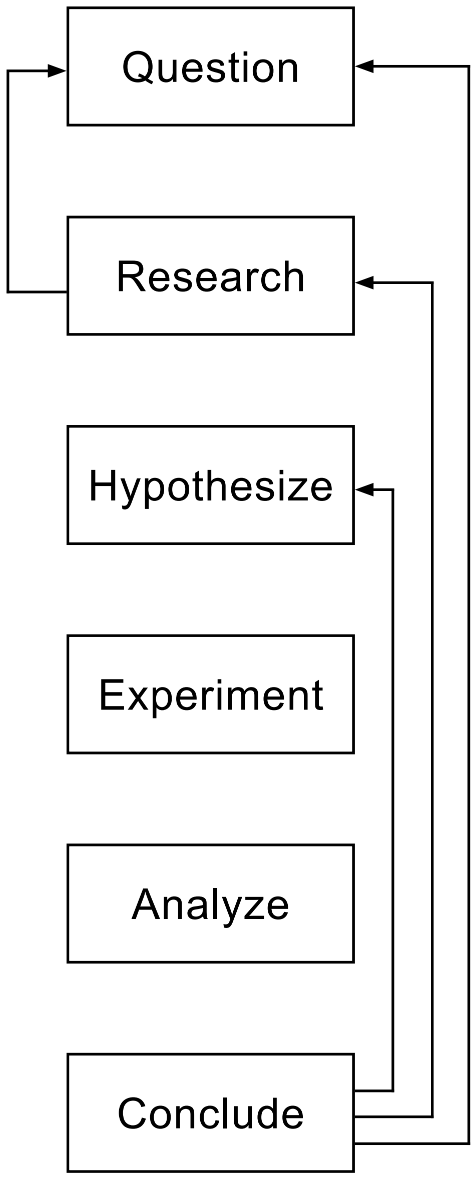
9. The constraints (or the limits) of the solution are:

10. Think about the problem of carbon emissions. In terms of designing a method to combat this issue, what are at least 2 things you need to learn in order to make an evidence-based recommendation? Make sure to consider all important aspects of the problem. Be specific.

1.C EDP and Scientific Inquiry Comparison



Engineering Design Process



Scientific Inquiry

1.D Client Letter

Dear Engineers,

Climate change is the concept that average conditions, such as rainfall or temperature, change over an extended period of time. This is an important topic because data suggests that the planetary changes we are experiencing have negatively impacted human health and the environment through air pollution, extreme weather events, inability to grow food, and other factors. The primary reason attributed to climate change is carbon emissions, which have increased 200% in the past 50 years.

Carbon sequestration is the process of capturing and storing atmospheric carbon dioxide to combat climate change. One method of carbon sequestration utilizes an environmental tool called a carbon sink. A carbon sink is anything that absorbs more carbon than it produces. A few examples of carbon sinks include plants, the ocean, and soil.

My company works with power plants that have high carbon emissions. Our goal is to generate solutions that decrease their environmental impact. This is especially important because the energy production sector is responsible for approximately 25% of global carbon emissions. My client's power plant that has requested assistance is located in the same county as your school. I want to enlist your help to provide us with a design of how we can use the empty areas of the property next to the power plant to reduce their high CO2 emissions.

Please use the engineering design process, science and mathematics knowledge, and your ingenuity to make an evidence-based recommendation for us. Please include this recommendation in your final report so we know why you have come to your solution. Note that this recommendation must be reliable, cost-effective, ethical, and demonstrate the use of scientific reasoning. We look forward to reading your report and implementing your result.

Sincerely,

Cole Wattson

Cole Wattson
Environmental Engineer
REFINES (Reducing Emissions From INdustrial Energy Stacks)

1.E Content Pre-Assessment Key

1. List five steps of the carbon cycle.

   Correct answers include decomposition, sedimentation, soil respiration, combustion, respiration, photosynthesis, dissolution, diffusion, and human activity.

2. How does a microelectronic sensor measure atmospheric carbon?

   The sensor emits an infrared light that is absorbed by a receiver. A microchip then converts the absorption into a carbon concentration.

3. What is environmental justice?

   Environmental justice is the pursuing the belief that regardless of color, race, gender, socioeconomic status, religion, or anything else, every person has the right to a clean and healthy environment.

4. How do carbon emissions negatively impact the environment?

   Carbon is a greenhouse gas that increases the temperature of the earth, causing climate change.

5. Explain what happens during photosynthesis. Write the chemical equation for photosynthesis.

   During photosynthesis, the organism absorbs solar energy and uses carbon dioxide and water to produce chemical energy in the form of glucose (with oxygen as a byproduct).

   $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

6. Explain cellular respiration and its purpose.

   Cellular respiration is the process that breaks down glucose to produce ATP (energy). This is important so that the cell has energy to complete other processes, such as signaling, transport, and DNA and RNA synthesis.

7. What does the term, “microelectronics” mean?

   Student answers may vary, but the formal definition of microelectronics is the design, manufacture, and use of microchips.

8. How are microelectronics used in the field of biology?

   There are many answers to this question, but one example is microchips in sensors.

9. What jobs would you be interested in that use microelectronics?

   Students’ answers will vary based on interest. Credit may be given as long as at least one job example is provided.

10. Provide one example of how microelectronics is used in that job.

    Students’ answers will vary based on interest. Credit may be given as long as at least one example is provided of how microelectronics is used in the job they provided in question nine.

1.F Problem Scoping Section 3 Key

Section 3:

4. The client is:

   Cole Wattson, an environmental engineer who works for REFINES.

5. The client's problem is:

   Power plants emit too much carbon and need methods to reduce their environmental impact.

6. The problem is important to solve because:

   Climate change has a negative impact on human health and the environment. Designing and implementing carbon sinks can help the client reduce the impacts of climate change in the future.

7. The end-users are:

   The power plant in our county.

8. An effective solution for the client will meet the following criteria:

   The solution should be reliable, cost effective, ethical, and demonstrate the use of scientific reasoning.

9. The constraints (or the limits) of the solution are:

   The solution must be on the property of the power plant.

10. Think about the problem of carbon emissions. In terms of designing a method to combat this issue, what are at least 2 things you need to learn in order to make an evidence-based recommendation? Make sure to consider all important aspects of the problem. Be specific.

    Student answers will vary. Potential ideas include how carbon sinks absorb carbon, how much extra room the power plant has for a carbon sink, methods to determine if the carbon concentration is less than before, etc.

LESSON TWO:

Lesson Objectives
Students will be able to:
- Explain each step of the carbon cycle
- Identify the relationship between the carbon cycle, photosynthesis, and cellular respiration
- Explain the impact of carbon emissions

Time Required
One 50-minute lesson

Materials
Per classroom
- EDP Poster

Per student
- EDP slider and paperclip
- Laptop/Chromebook/ Tablet
- Engineering notebook
- Pencils and erasers
- 1 die

Standards Addressed
- NGSS: HS-LS2-5, 2-LS2-1

Key Terms
Carbon cycle, energy transfer, photosynthesis, respiration, decomposition

Lesson Summary

The carbon cycle is an important concept to learn as students will be attempting to reduce the concentration of carbon emitted into the atmosphere. After briefly reviewing the carbon cycle, students will play a dice game where each student acts as a carbon molecule moving through the cycle. The lesson will conclude with a review of why it is important to reduce carbon emissions.

Background

Teacher Background

- Climate Change Resource
  - https://www.youtube.com/watch?v=OtfuYIhDjw4
- Carbon Sequestration Resource
  - https://www.doi.gov/ppa/seminar_series/video/carbon-sequestration

Before the Activity

- Choose six stations around the room where students can stand at to roll their die.
- At each station, place one of the six instruction sheets (Duplication Masters 2.E – 2.J).
- The class will be divided into six groups, and each group will start at one of the six stations. Put the correct number of dice at each station so students can pick it up on their first turn.

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Learn). Say:** *So far, we have defined the problem with help from our client.* Point out the "Problem" block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the "Learn" stage.
3. **Read the client memo.** Hand out Duplication Master 2.A Client Memo 1. Allow students a few minutes to read the memo.

Activity

4. **Review the carbon cycle.** Hand out Duplication Master 2.A The Carbon Cycle and briefly walk students through each of the steps which are transitioning between the atmosphere, animals, plants, decay, fossil fuels, and factories.
5. **Introduce the game.** Hand out Duplication Master 2.B Carbon Journey Tracker. **Say:** *Each of you is a carbon molecule going on a journey through the carbon cycle. You will see what it is like to experience the different processes like photosynthesis, cellular respiration, and decomposition.*
6. **Prepare for the game.** Split the class into six groups and have each group start at a different station. **Say:** *When I say you can begin, you can pick up a die at your station and take your first turn. You will roll the die ten times for a total of ten turns. After each roll, write down what happened on your Journey Tracker. You will carry your die with you to each station.* When the teacher is ready, they will let the students begin.

Closure

7. **Connect the activity to the engineering design challenge. Ask:** *What did we learn today that will help us provide a recommendation to the client? What part of the carbon cycle are we working within for our challenge? What are we hoping to do with the carbon emissions that come from power plants?* **Say:** *We will continue in the Learn stage during our next class.*

Duplication Masters

2.A Client Memo 1
2.B The Carbon Cycle
2.C Carbon Journey Tracker
2.D My Carbon Journey

Educator Resources

2.E Carbon Cycle Game: Animals
2.F Carbon Cycle Game: Atmosphere
2.G Carbon Cycle Game: Factories
2.H Carbon Cycle Game: Fossil Fuels
2.I Carbon Cycle Game: Plants
2.J Carbon Cycle Game: Soil

2.A Client Memo 1

Dear Engineers,

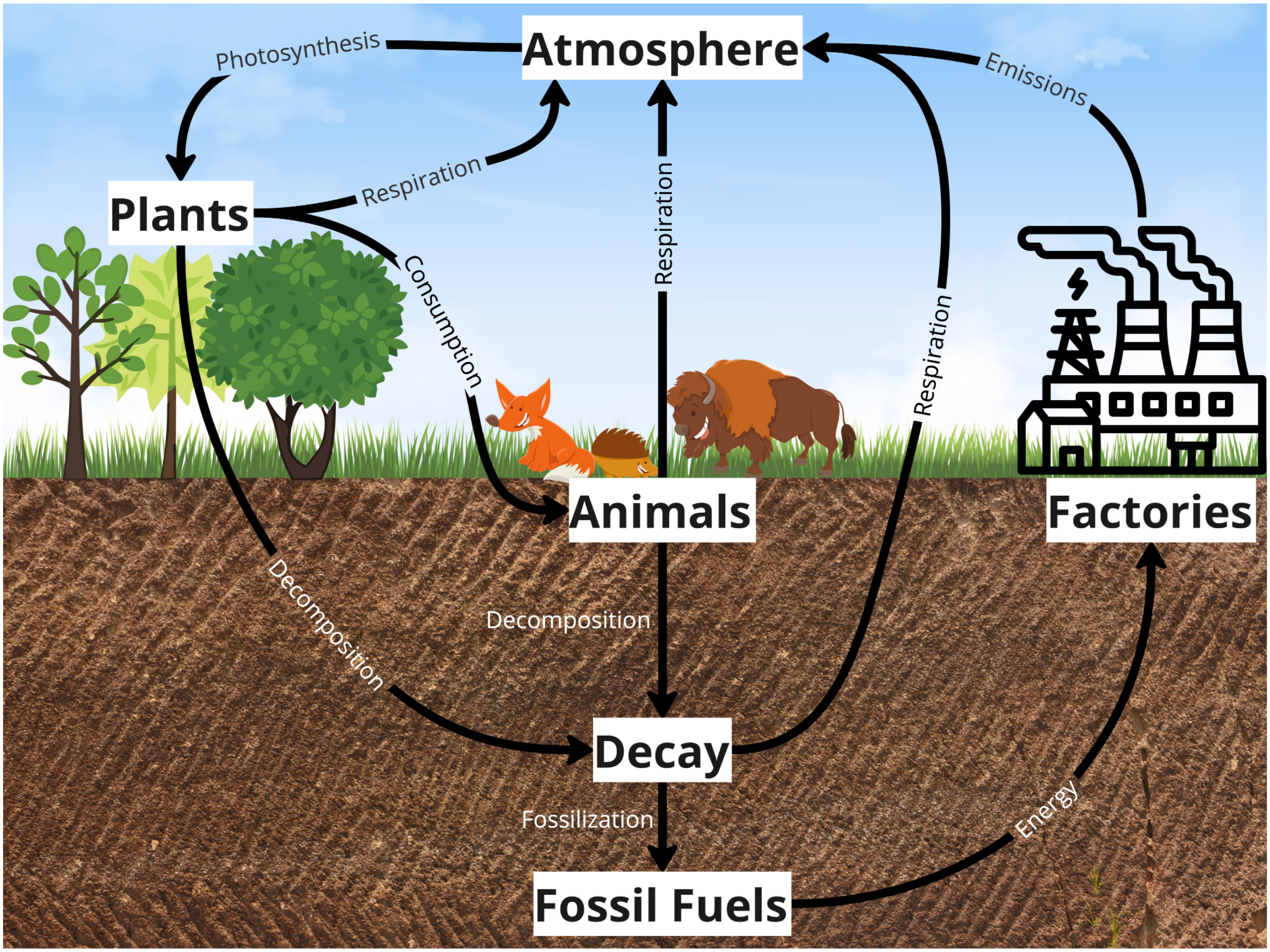
Thank you for agreeing to work with us on our engineering design challenge. Before you can begin solving the problem, it is important to learn relevant information to ensure you fully understand the context. I have prepared a few lessons for you about fossil fuels and the environment, the carbon cycle, photosynthesis, and cellular respiration. I hope you find these activities helpful as we continue working toward reducing carbon emissions.

Sincerely,

Cole Wattson

Cole Wattson
Environmental Engineer
REFINES (Reducing Emissions From INdustrial Energy Stacks)

2.B The Carbon Cycle



Name____ Date_______________ Period __________

2.C Carbon Journey Tracker

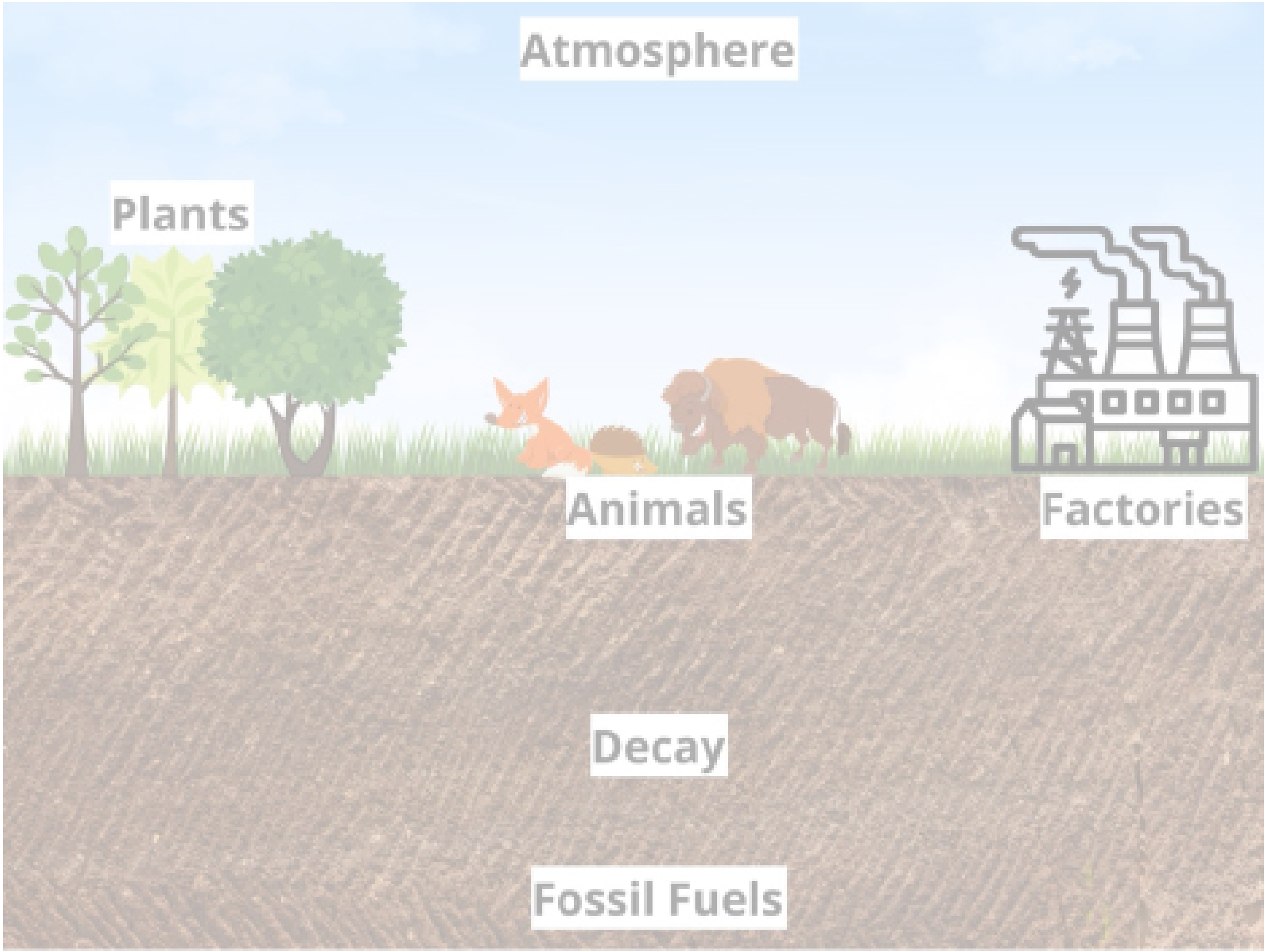
At the start of each turn, write down your location. Then write down the process that you experienced (e.g., photosynthesis, carbon emission, cellular respiration, etc.). Finally, write down where you ended your turn.

Turn	Location at Start of Turn	Process You Experienced	Final Destination
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

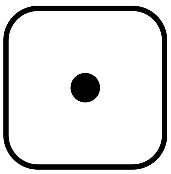
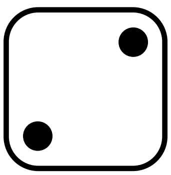
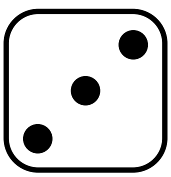
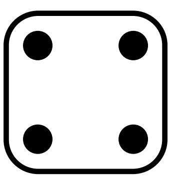
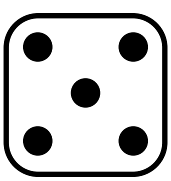
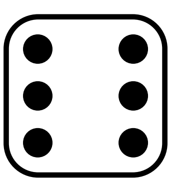
Name______________________________________ Date______________ Period ___________

2.D My Carbon Journey

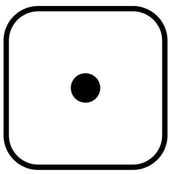
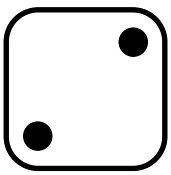
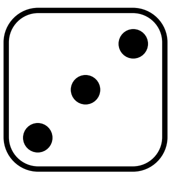
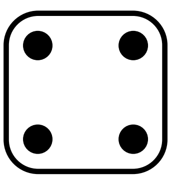
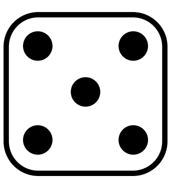
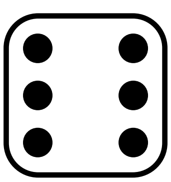
Using your carbon journey tracker, draw the path you took from turn 1 all the way through turn 10. Compare with other students to see how your paths may have differed.



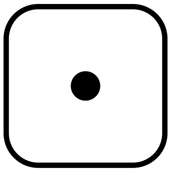
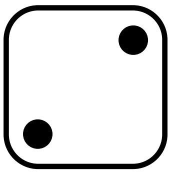
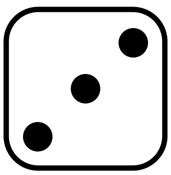
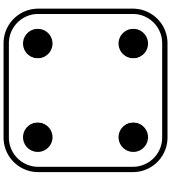
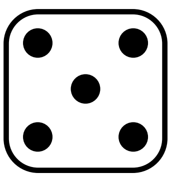
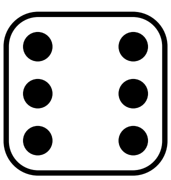
2.E Carbon Cycle Game – Animals

Animals		
If you rolled a…	**…you experience this…**	**…and move/stay here!**
	You are just hanging out in your animal.	STAY IN: **Animals**
	You are just hanging out in your animal.	STAY IN: **Animals**
	You have been eaten by a predator! You are now hanging out in a new animal.	STAY IN: **Animals**
	Your animal took a deep breath and respired you out as carbon dioxide.	MOVE TO: **Atmosphere**
	Your animal took a deep breath and respired you out as carbon dioxide.	MOVE TO: **Atmosphere**
	Your animal passed away peacefully. You have been returned to the soil.	MOVE TO: **Soil**

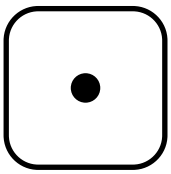
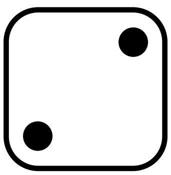
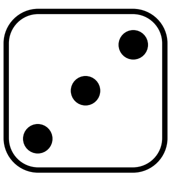
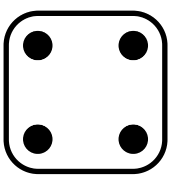
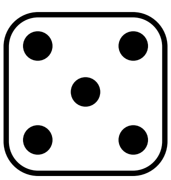
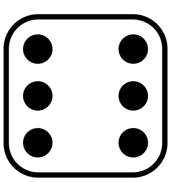
2.F Carbon Cycle Game – Atmosphere

Atmosphere		
If you rolled a…	**…you experience this…**	**…and move/stay here!**
	You are floating through the atmosphere.	STAY IN: **Atmosphere**
	You are floating through the atmosphere.	STAY IN: **Atmosphere**
	You are floating through the atmosphere.	STAY IN: **Atmosphere**
	You are floating through the atmosphere.	MOVE TO: **Atmosphere**
	You are a key contributor during photosynthesis!	MOVE TO: **Plants**
	You are a key contributor during photosynthesis!	MOVE TO: **Plants**

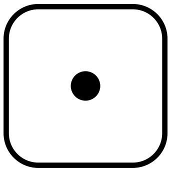
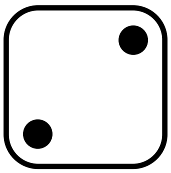
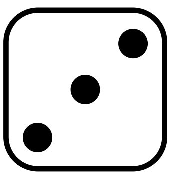
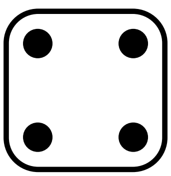
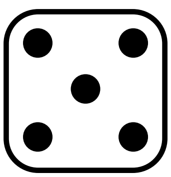
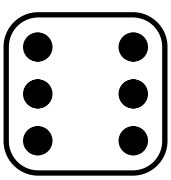
2.G Carbon Cycle Game – Factories

Factories		
If you rolled a…	**…you experience this…**	**…and move/stay here!**
	You are still being transformed into energy.	STAY IN: **Factories**
	You are still being transformed into energy.	STAY IN: **Factories**
	You are still being transformed into energy.	STAY IN: **Factories**
	You are a carbon emission…	MOVE TO: **Atmosphere**
	You are a carbon emission…	MOVE TO: **Atmosphere**
	You are a carbon emission…	MOVE TO: **Atmosphere**

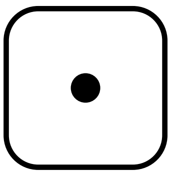
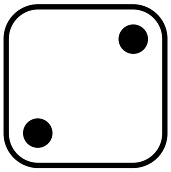
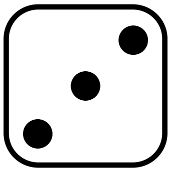
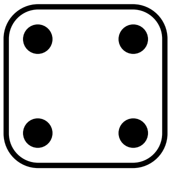
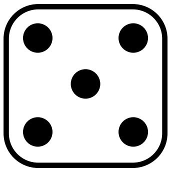
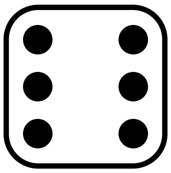
2.H Carbon Cycle Game – Fossil Fuels

Fossil Fuels		
If you rolled a…	**…you experience this…**	**…and move/stay here!**
	Being a fossil fuel is chill.	STAY IN: **Fossil Fuels**
	Being a fossil fuel is chill.	STAY IN: **Fossil Fuels**
	Being a fossil fuel is chill.	STAY IN: **Fossil Fuels**
	Being a fossil fuel is chill.	MOVE TO: **Fossil Fuels**
	Being a fossil fuel is chill.	MOVE TO: **Fossil Fuels**
	You are being utilized for energy!	MOVE TO: **Factories**

2.I Carbon Cycle Game – Plants

Plants		
If you rolled a…	**…you experience this…**	**…and move/stay here!**
	You are just hanging out in a tree's roots.	STAY IN: **Plants**
	You are just hanging out in a tree's roots.	STAY IN: **Plants**
	You are just hanging out in a tree's branches.	STAY IN: **Plants**
	You have been consumed by an animal of your choice!	MOVE TO: **Animals**
	You experience cellular respiration.	MOVE TO: **Atmosphere**
	Your tree has decomposed.	MOVE TO: **Soil**

Soil

If you rolled a…	…you experience this…	…and move/stay here!
	You are being stored.	STAY IN: **Soil**
	You are being stored.	STAY IN: **Soil**
	You are being stored.	STAY IN: **Soil**
	The soil took a deep breath and respirated. You have been released!	MOVE TO: **Atmosphere**
	You have remained in the soil so long that you have become a resource!	MOVE TO: **Fossil Fuels**
	You have remained in the soil so long that you have become a resource!	MOVE TO: **Fossil Fuels**

LESSON THREE:

Lesson Objectives
Students will be able to:
- Explain why it is important to keep track of atmospheric carbon emissions
- Explain how an atmospheric carbon sensor works
- Define the term, "microelectronics"

Time Required
One 50-minute lesson

Materials
Per classroom
- EDP Poster

Per student
- EDP slider and paperclip
- Laptop/Chromebook/Tablet
- Engineering notebook
- Pencils and erasers

Standards Addressed
- NGSS: LS2.B

Key Terms
Microelectronics, sensors, Beer-Lambert Law, infrared

Lesson Summary

An important part of this engineering design challenge involves measuring atmospheric CO2. In this lesson, students will learn why having an accurate measure of CO2 is important to combating climate change. They will also learn how a sensor can accurately measure this gas, and why each component is important.

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Learn). Say:** *So far, we have defined the problem with help from our client and learned about the carbon cycle.* Point out the "Problem" block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the "Learn" stage.

Activity

3. **Discuss the importance of measuring atmospheric carbon. Ask:** *Why is it important that we know how much carbon is in the atmosphere? What does atmospheric carbon impact?* Lead a discussion that helps students identify that excess carbon in the atmosphere leads to climate change. Therefore, we need to track the concentration (amount) of carbon so we can track climate change.
4. **Discuss relevant regulations relating to carbon emissions. Say:** *The United States Environmental Protection Agency, also called the USEPA, sets regulations about environmental health. In May of 2023, the USEPA proposed the Clean Air Act emission limits, which specifically identifies guidelines for carbon dioxide emissions from fossil fuel-fired power plants.*
5. **Discuss how sensors work. Say:** *We know it is important for carbon dioxide emissions to have regulations, and so we know it is important that we have a way to accurately measure them. But how do we measure them? How does a sensor operate? What is happening inside of the device?* Tell students that it is important to use microelectronic sensors since they are the most accurate method of measuring atmospheric carbon. Hand out Duplication Master 3.A Atmospheric CO_2 Sensor Diagram.
6. **Explain how sensors work. Say:** *Sensors are microelectronic devices used to measure a variable. The term, "microelectronic"*

means the design, manufacture, and use of microchips. The microelectronic atmospheric carbon sensor has four primary components. There is a place for gas to go in, and a place for gas to go out. There is also an infrared source that emits infrared through the sensor. And finally, there is a receiver for the infrared light and a microchip. The receiver measures the amount of infrared light based on something called absorption. This is how much light was absorbed as compared to how much light was emitted. Using this difference, the microchip calculates the concentration of atmospheric carbon and outputs a concentration value.

NOTE: It is important that the teacher defines the word, "microelectronics" during this lesson. This step would be a good time to do so.

Activity Option #1

7. **Show students how to use the atmospheric carbon sensor.** Provide a brief tutorial of how the sensor should be used, ensuring that everyone understands how fragile the sensor is.
8. **Take measurements with the atmospheric carbon sensor.** Allow students time to use the sensor to take measurements in the room. This will provide them with practice that will be helpful when making measurements for their carbon sinks.

Activity Option #2

7. **Introduce the Beer-Lambert Law. Say:** *There is an equation that helps explain the relationship between the infrared source, the infrared received, and the concentration of atmospheric carbon. This equation is called the Beer-Lambert Law.* Explain what each variable represents.
   a. A represents absorbance, which is the amount of infrared light absorbed by the sensor. Note that since there is gas between the infrared source and the infrared receiver, the amount of light changes.
   b. ε represent molar absorptivity. This is a constant value. Each molecule has a value for this variable, and that number will never change for that specific molecule. For atmospheric carbon, our value is 3.862 ($L * g^{-1} * cm^{-1}$).
   c. C represents the concentration of atmospheric carbon.
   d. ℓ is the length between the infrared source and the infrared sensor. This is important because since the gas is blocking some of the infrared light from passing all the way through to the sensor, we need to know how far apart the source and sensor are.

Duplication Masters

3.A Atmospheric CO2 Sensor Diagram

3.B Beer-Lambert Law Worksheet

Educator Resources

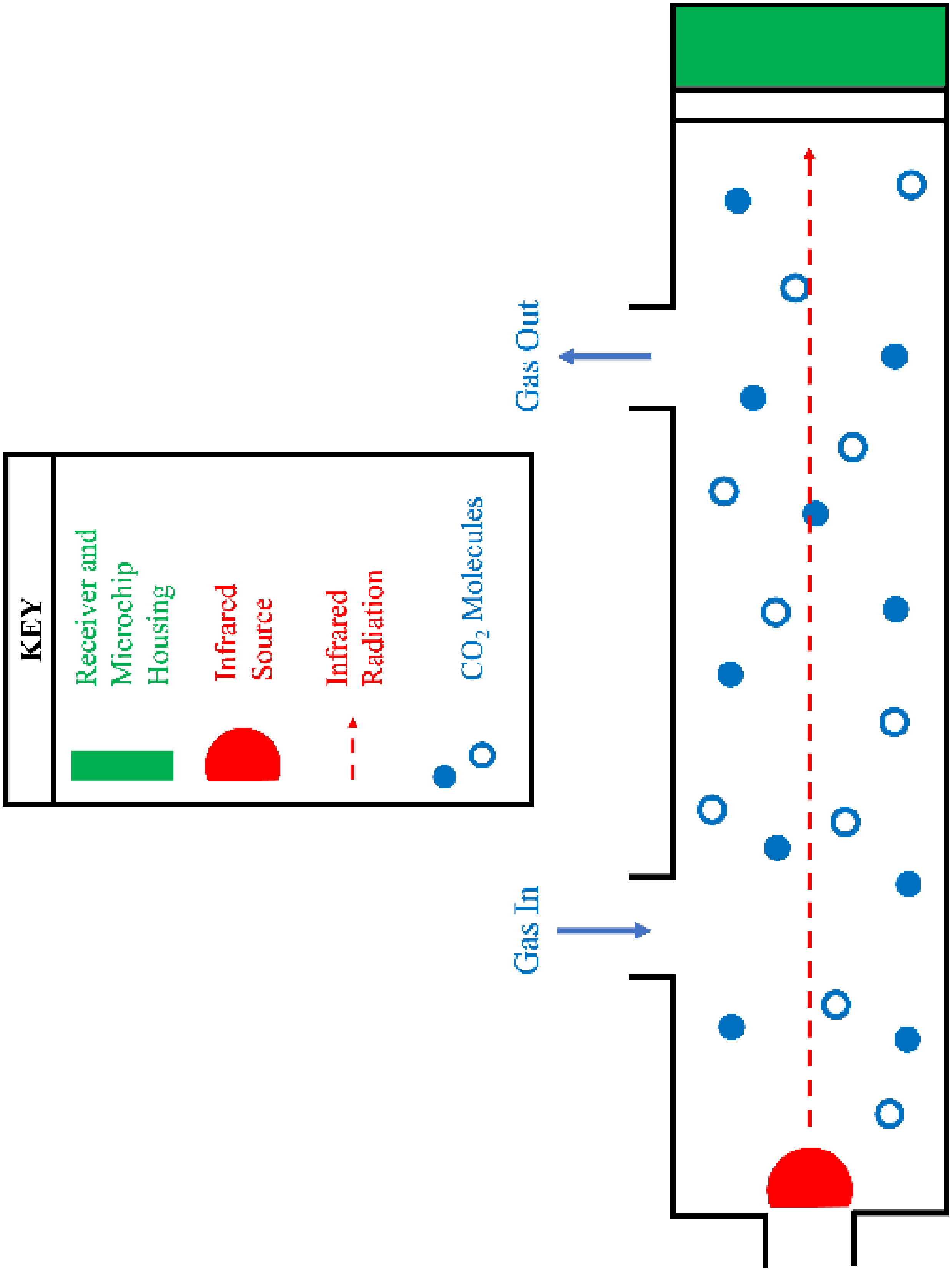
3.C Beer-Lambert Law Worksheet Answers

8. **Complete the Beer-Lambert Law activity.** Hand out Duplication Master 3.B Beer-Lambert Law worksheet. Allow students time to work individually or in groups through the worksheet. Walk around and answer questions as needed. **NOTE:** Teachers may choose to include or exclude units. Since the units are complicated, it will depend on the student group if they are able to perform dimensional analysis or not.

Closure

9. **Connect the activity to the engineering design challenge.** **Ask:** *What did we learn today that will help us provide a recommendation to the client? Why are sensors important for measuring atmospheric CO_2? How have microelectronics improved the field of biology?* **Say:** *We will continue in the Learn phase during our next class.*

3.A Atmospheric CO2 Sensor Diagram



Name______________________________________ Date______________ Period __________

3.B Beer-Lambert Law Worksheet

1. **Solve the Beer-Lambert Law for the concentration term.**

   Beer-Lambert Law: $A = \varepsilon * C * \ell$

   A = Absorbance
   ε = Molar Absorptivity
   C = Concentration
   ℓ = length (between infrared source and sensor)

2. **The molar absorptivity for CO2 is 3.862. The length between your sensor's infrared source and the sensor is 30. Assume that the sensor measured an absorbance of 0.351 outside the power plant. Would this meet a regulation of being below a concentration of 0.005? Answer the question in a full sentence.**

Name_______________________________________ Date_______________ Period __________

3.C Beer-Lambert Law Worksheet Answers

1. Solve the Beer-Lambert Law for the concentration term.

Beer-Lambert Law: $A = \varepsilon * C * \ell$

A = Absorbance
ε = Molar Absorptivity
C = Concentration
ℓ = length (between infrared source and sensor)

$$C = \frac{A}{\varepsilon * \ell}$$

2. The molar absorptivity for CO2 is 3.862. The length between your sensor's infrared source and the sensor is 30. Assume that the sensor measured an absorbance of 0.351 outside the power plant. Would this meet a regulation of being below a concentration of 0.005? Answer the question in a full sentence.

NOTE: If the teacher would like to include units, they are given here in the answer. If they will only be a distraction for students to try and perform dimensional analysis, you can keep them out of the problem.

$$C = \frac{A}{\varepsilon * \ell}$$

$$C = \frac{0.351}{\left(3.862 \frac{L}{g * cm}\right) * (30\ cm)}$$

$$C = 0.003\ g$$

This power plant does meet the regulations because the concentration is below the limit of 0.005.

LESSON FOUR:

Lesson Objectives
Students will be able to:
- Define environmental justice
- Define climate justice
- Make connections between environmental justice and climate change
- Discuss one method of carbon sequestration that can alleviate injustice

Time Required
One 50-minutes lesson

Materials
Per classroom
- EDP Poster

Per student
- EDP slider and paperclip
- Laptop/Chromebook/ Tablet
- Engineering notebook
- Pencils and erasers

Standards Addressed
- NGSS: LS2.B

Key Terms
Carbon emissions, carbon sequestration, environmental justice, social justice

Lesson Summary

Students will learn the definitions for climate justice and environmental justice. After discussing how this relates to their engineering design challenge, students will read a new client memo. This memo asks students to research methods of carbon sequestration that can alleviate environmental and social injustice.

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Learn). Say:** *So far, we have defined the problem with help from our client and learned about the carbon cycle and sensors.* Point out the “Problem” block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the “Learn” stage.

Activity

3. **Identify solutions to the problem. Ask:** *If you live near a power plant, how can you avoid breathing in excess carbon? What if moving further away from it is not an option?* Help students understand that not everyone is able to move away from the problem, and there is not always funding to create a carbon sink at every power plant. **Ask:** *Is it fair that some people have no choice but to breathe in excess carbon?* **Say:** *This is why it is so important that we help our client! Even if some people are safe and some people are in danger, EVERYONE should have access to a clean and healthy environment.*
4. **Facilitate a discussion about environmental justice.** Either on the board or a projector, show the definition of environmental justice: every person, regardless of race, color, national origin, income, socioeconomic status, or religion, have the right to a clean and healthy environment. **Ask:** *How does this definition relate to our client’s problem?* Help students identify that people who live closer to the power plant are more likely to breathe in excess CO_2.
5. **Show an environmental justice video.** Show the video linked below (4.5 minutes) that will teach students about the importance of pursuing environmental justice.

- https://youtu.be/0L2xCwD5RNI?si=TM7uTVFEpnDOants

6. **Read the client memo.** Hand out Duplication Master 4.A Client Memo 2. Read together as a group or allow students a minute to read the letter. **Say:** *For the rest of class today, your client would like you to research methods of carbon sequestration. Choose one method and write a paragraph about how it can help alleviate environmental injustice.*
7. **Write the climate and environmental justice paragraphs.** Hand out Duplication Master 4.B Paragraph Requirements. **Say:** *Follow the guidelines from our client to write your letter.*
    - **NOTE:** Ideally, at least one or two students use the recommendation of focusing on algae farms. This provides the context for Client Memo 3 where the client states that students will use algae farms based on the research they did during this class activity.

Closure

8. **Connect the activity to the engineering design challenge.** **Ask:** *What did we learn today that will help us provide a recommendation to the client? What is environmental justice? What is climate justice? Why are these two ideas important?* **Say:** *We will continue in the Learn stage during our next class.*

Duplication Masters

4.A Client Memo 2

4.B Paragraph Requirements

4.A Client Memo 2

Dear Engineers,

Thank you for continuing to learn relevant information for our engineering design challenge. One important role of an engineer is to adhere to the Engineering Code of Ethics. This code states that we will not harm people or the environment with our work. These are very important codes to follow. Therefore, I have asked your teacher to introduce you to environmental justice and climate justice.

For the rest of today's class, please spend time researching methods of how to alleviate carbon emission injustice. Choose one method that you think is best, and then come up with a few reasons why you think your method is a good idea and write at least one paragraph defending your choice. A few common carbon sequestration methods are algae farms, forests, and oceans. I have attached guidelines for you to follow while writing your paragraph.

Sincerely,

Cole Wattson

Cole Wattson
Environmental Engineer
REFINES (Reducing Emissions From INdustrial Energy Stacks)

4.B Paragraph Requirements

- Explain why it is important to reduce carbon emissions
- Provide definitions (in your own words!) for environmental justice and climate justice.
- Describe your chosen method of carbon sequestration.
- Explain why this method is effective in pursuing environmental justice and/or social justice.

LESSON FIVE:

Lesson Objectives
Students will be able to:
- Identify the reactants and products of photosynthesis
- Explain the importance of photosynthesis to the carbon cycle
- Understand the basic process involved in photosynthesis
- Identify factors that affect the rate of photosynthesis

Time Required
One 50-minute lesson

Materials
Per classroom
- EDP Poster
- Label tape
- Bromthymol blue solution

Per group (3 per group)
- Two 125-mL flasks
- 2 rubber stoppers for 125-mL flasks
- Marker
- 100-mL graduated cylinder
- Drinking straw
- 2 sprigs of Elodea

Per student
- EDP slider and paperclip
- Laptop/Chromebook/Tablet
- Engineering notebook
- Pencils and erasers
- Safety glasses
- Latex gloves

Standards Addressed
- NGSS: HS-LS2-5, 2-LS2-1

Lesson Summary

Students will learn about photosynthesis and cellular respiration through a lab that demonstrates the two processes. After reviewing the equation that converts light energy into chemical energy, students will work together in groups on the lab.

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Learn). Say:** *So far, we have defined the problem with help from our client and learned about the carbon cycle, sensors, and environmental justice.* Point out the "Problem" block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the "Learn" stage.

Activity

3. **Briefly review the topic of photosynthesis. Ask:** *What is the goal of photosynthesis?* Help students get to the definition of converting light energy into chemical energy. Write the equation for photosynthesis on the board or show it on your screen.

$$6CO_2 + 6H_2O + light \rightarrow C_6H_{12}O_6 + 6O_2 + H_2O$$

4. **Introduce the activity. Say:** *In our activity today, we will be observing both photosynthesis and cellular respiration.*
5. **Allow students time to complete the first phase of the lab.** Hand out Duplication Master 5.A Photosynthesis and Cellular Respiration Lab and Duplication Master 5.B Data Collection Table. When they have finished steps 1 and 2, help students find a place for their flasks to be stored in light and dark areas.

Closure

6. **Connect the activity to the engineering design challenge.** **Ask:** *What did we learn today that will help us provide a recommendation to the client? What chemicals are required for photosynthesis to occur? How does the presence of carbon dioxide relate to our engineering design challenge?* **Say:** *We will continue in the Learn stage during our next class.*

Key Terms
Photosynthesis, chemical reaction, chloroplast, stroma

Duplication Masters
5.A Photosynthesis and Cellular Respiration Lab
5.B Data Collection Table

Photosynthesis and Cellular Respiration Lab

Materials:

- Safety glasses
- Gloves
- Two 125-mL flasks
- Label tape
- Marker
- 100-mL graduated cylinder
- Bromthymol blue solution
- Drinking straw
- 2 sprigs of Elodea
- 2 rubber stoppers
- Light source
- Dark area

Instructions

1. Prepare your materials for the experiment.
    a. Put on safety glasses and gloves.
    b. Label your flasks “Flask A” and “Flask B” with the label tape and marker.
    c. Using a graduated cylinder, measure 100 mL bromthymol blue solution into each of the blue flasks. CAUTION: Bromthymol blue is a dye and can stain your hands and clothing.
    d. In the Data Collection Table within the Day 1: Initial Observations column, make an observation about the appearance of both of the flasks.
2. Complete part one of the experiment.
    a. Insert one end of a drinking straw into Flask A. Gently blow through the straw until there is a change of appearance to the solution.
    b. Record any observations in the Data Collection Table within the Day 1: Secondary Observations column.
    c. Place a sprig of Elodea into the flask.
    d. Place your stopper on the flask to ensure it is airtight.
    e. Repeat steps 2a, 2b, and 2c with Flask B.
3. Place the flasks in their light and dark areas for 24 hours.
    a. Place Flask A on a sunny windowsill for 24 hours. Artificial light may be used if natural light is not available.
    b. Place Flask B in the dark for 24 hours.

5.B Data Collection Table

	Flask A	Flask B
Day 1: Initial Observations		
Day 1: Secondary Observations		
Day 2 Observations		

LESSON SIX:

Lesson Objectives
Students will be able to:

- Identify the relationship between photosynthesis and cellular respiration
- Identify the reactants and products of cellular respiration
- Understand the importance of cellular respiration to the carbon cycle
- Identify factors that affect the rate of cellular respiration
- Explain the transfer of energy occurring within the process

Time Required
One 50-minute lesson

Materials
Per classroom

- EDP Poster

Per student

- EDP slider and paperclip
- Laptop/Chromebook/Tablet
- Engineering notebook
- Pencils and erasers

Standards Addressed

- NGSS: HS-LS2-5, 2-LS2-1

Key Terms
Cellular respiration, aerobic respiration, anaerobic respiration, energy, ATP

Lesson Summary

Students will learn about cellular respiration and the equation components. After reviewing that glucose and oxygen are vital for cellular respiration to occur, students will work through lab questions in groups.

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Learn). Say:** *So far, we have defined the problem with help from our client and learned information about the carbon cycle, sensors, environmental justice, and photosynthesis.* Point out the “Problem” block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the “Learn” stage.

Activity

3. **Briefly review the topic of cellular respiration. Ask:** *What is the equation for cellular respiration? What is required for it to occur?* Help students get to the equation below. Either write it on the board or project it on a screen to the class.

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP$$

4. **Introduce the activity. Say: T***oday, we will continue our lab from yesterday, make observations about the experiment, and discuss what has happened.*
5. **Have students work through the activity for the remainder of class.** Hand out Duplication Master 6.A Lab Discussion. Students should work in their groups from the previous day to complete all of the questions.
6. **Discuss the answers to the lab questions.** Use Educator Resource 6.B Lab Discussion Answers to help students walk through the answers.

Closure

7. **Connect the activity to the engineering design challenge.** **Ask:** *What did we learn today that will help us provide a recommendation to the client? What does cellular respiration teach us about carbon sinks?* **Say:** *We will move to the Plan stage during our next class.*

Duplication Masters

6.A Lab Discussion

Name____ Date_______________ Period __________

6.A Lab Discussion

Answer the following questions within your group.

1. What substance was released into the bromthymol blue solution when you exhaled into it?

2. How was this substance produced? Use proper terminology.

3. Why did the color of the bromthymol blue solution change after you exhaled into it?

4. Why was Elodea placed in both flasks?

Name______________________________________ Date______________ Period __________

5. Which flask served as the control for this experiment? Why do you think that one was the control?

6. How are photosynthesis and cellular respiration related?

7. Why did one flask change colors while the other did not? Justify your answer using the concepts of photosynthesis and cellular respiration.

8. How would you demonstrate that Elodea carries out photosynthesis at a faster rate than it carries out respiration?

6.B Lab Discussion Answers

Answer the following questions within your group.

1. What substance was released into the bromthymol blue solution when you exhaled into it?

   Answer

2. How was this substance produced? Use proper terminology.

   Answer

3. Why did the color of the bromthymol blue solution change after you exhaled into it?

   Answer

4. Why was Elodea placed in both flasks?

   Answer

5. Which flask served as the control for this experiment? Why do you think that one was the control?

Answer

6. How are photosynthesis and cellular respiration related?

Answer

7. Why did one flask change colors while the other did not? Justify your answer using the concepts of photosynthesis and cellular respiration.

Answer

8. How would you demonstrate that Elodea carries out photosynthesis at a faster rate than it carries out respiration?

Answer

LESSON SEVEN:

Lesson Objectives
Students will be able to:
- Design solutions to an engineering design challenge
- Use evidence-based reasoning while designing a solution to a problem
- Write a standard operating procedure

Time Required
One 50-minute lesson

Materials
Per classroom
- EDP Poster

Per student
- EDP slider and paperclip
- Laptop/Chromebook/Tablet
- Engineering notebook
- Pencils and erasers

Standards Addressed
- NGSS: HS-ETS1-3

Key Terms
Brainstorm, mind map, sketch

Lesson Summary

Now that students have learned about the fossil fuels, the carbon cycle, cellular respiration, photosynthesis, and sensors, they are ready to develop their ideas into a solution to the engineering design challenge. Students will work individually and in teams to brainstorm different algae configurations. Using evidence-based reasoning, they will make a decision as a team.

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Plan). Say:** *So far, we have defined the problem with help from our client and learned relevant information.* Point out the “Problem” block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the “Plan” stage.
3. **Read the client memo.** Hand out Duplication Master 7.A Client Memo 3. Allow students a few minutes to read the memo. **Ask:** *How has our engineering design challenge changed based on this memo? Do we have any new criteria or constraints?*

Activity

4. **Review the algae strain information.** Hand out Duplication Master 7.B Algae Strain Information and allow students a few minutes to read through. They may have some questions about the included characteristic information:
    - **Growth Rate:** This is how quickly the algae will grow. The higher the value, the faster it grows.
    - **Light Intensity:** This is how much light the algae need to flourish. The higher the value, the more light it needs.
    - **Optimum Temperature:** Students should consider the temperature in the classroom since they will not be provided heat lamps or cooling areas to change the temperature of their algae farm.
    - **Motility:** This describes how much the algae moves using metabolic energy.
5. **Brainstorm ideas individually.** Hand out Duplication Master 7.C Evidence-Based Reasoning. **Say:** *Come up with two ideas that you think would do the best job of reducing carbon in the atmosphere. Answer the questions for each idea.*

6. **Gather into pre-determined design teams to discuss their designs. Say:** *Now that you have come up with some ideas on your own, work in your teams to review your ideas and determine which idea is the best.* Allow the students a few minutes to discuss.
7. **Come to a consensus on the best design in each group. Say:** *Within your design teams, choose your top idea that you would like to move forward with as your proposed algae farm.*
8. **Prepare a standard operating procedure (SOP) for your algae farm.** Hand out Duplication Master 7.D Standard Operating Procedure. **Say:** *Now that you know which algae strains you will use, it is time to write a procedure for how you will build your algae farm. Include a list of materials you will need and the instructions for how the farm should be built.*

Closure

9. **Connect the activity to the engineering design challenge. Ask:** *What did we learn today that will help us provide a recommendation to the client? Why do algae farms make a good carbon sink? Why is it important to use evidence-based reasoning as an engineer?* **Say:** *We will move to the Try stage during our next class.*

Duplication Masters

7.A Client Memo 3
7.B Algae Strain Information
7.C Evidence-Based Reasoning
7.D Standard Operating Procedure

Educator Resources

This lesson and the engineering design challenge was adapted from the National Science Teachers Association resource: Engineering in the Life Sciences, 9-12.

Custer, R. L., Daugherty, J. L., Ross, J. M., Kennedy, K. B., & Culbertson, C. (2018). *Engineering in the life sciences*, 9-12. NSTA.

7.A Client Memo 3

Dear Engineers,

Thank you for continuing to work hard on preparing your carbon sink designs. Now that you have learned all the relevant information, I would like you to get started on brainstorming your designs. I read the paragraphs you wrote on carbon sequestration methods to alleviate environmental and climate injustice. I believe you made great points about algae farms – they do make a great carbon sink due to cellular respiration and photosynthesis. Algae farms absorb carbon and emit oxygen, which is exactly what we hope to achieve. Please use the list of algae strain options I have provided to choose from for your algae farm design.

It is important to test a small-scale design before we implement your idea on a large scale at the power plant. Please use a 2- or 3-quart plastic bin to grow your algae farm and plan to purchase 3 – 6 tubes. You will fill your container halfway with the medium of your choice and then add your algae. You may want to include barriers to keep different strains of algae separate, or not. Remember that your design should be reliable, cost-effective, and ethical.

Sincerely,

Cole Wattson

Cole Wattson
Environmental Engineer
REFINES (Reducing Emissions From INdustrial Energy Stacks)

7.B Algae Strain Information

Below is information about the four available algae strains.

Type of Algae	Growth Rate	Light Intensity (units)	Optimum Temperature (Celcius)	Salt Concentration of the Medium	Diameter (µM)	Color	Motility	Cost (per tube)
Chlorella vulgari	0.80	3,240	32.5	Freshwater	5 – 10	Green	Nonmotile	$10.40
Dunaliella salina	0.70	27,000	20 – 40	High salt water	10 – 12	Reddish pink	Motile	$7.30
Haematococcus	0.195	2,160	23 – 25	Low salt water	5 – 25	Red	Motile	$9.25
Tetraselmis	0.67	2,000	20 – 27	High salt water	10	Green	Motile	$7.30

Name_______________________________________ Date_______________ Period __________

7.C Evidence-Based Reasoning

Review the available algae strains and brainstorm which strain or combination of strains you would like to use for your design. Come up with your two top options and think through your reasoning for these choices.

Design Idea #1	
How many algae strains will you use for your algae farm? What are they?	
Why did you choose this/these specific strain(s)?	
If you have more than one strain, will you mix them or keep them separate? Why?	
Why do you think this design idea will work?	
What negative or unintended consequences could emerge from your design idea being implemented?	

Name____ Date_______________ Period __________

Design Idea #2	
How many algae strains will you use for your algae farm? What are they?	
Why did you choose this/these specific strain(s)?	
If you have more than one strain, will you mix them or keep them separate? Why?	
Why do you think this design idea will work?	
What negative or unintended consequences could emerge from your design idea being implemented?	

Name_______________________________________ Date_______________ Period ___________

7.D Standard Operating Procedure

With your team, write a procedure for how you plan to build your algae farm in your bin during the next class. Include a list of materials that you will need. Ensure you include enough detail in each step so that anyone who saw your procedure could easily follow it.

Material List

Instructions

Name______________________________________ Date_______________ Period __________

LESSON EIGHT:

Lesson Objectives
Students will be able to:
- Build an algae farm
- Measure atmospheric carbon

Time Required
One 50-minute lesson

Materials
Per classroom
- EDP Poster
- Vernier CO_2 Gas Sensor
- Vernier LabQuest 3

Per group (3 per group)
- Plastic divider bin with attached lid and dividers (link)
- Filtered water (must be free from chlorine)
- Salt
- Algae strains

Per student
- EDP slider and paperclip
- Laptop/Chromebook/ Tablet
- Engineering notebook
- Pencils and erasers
- Latex gloves
- Safety glasses

Standards Addressed
- NGSS: HS-ETS1-3

Key Terms
Algae farm, carbon emissions, sensors

Lesson Summary

In this lesson, students will build their algae farms based on the standard operating procedure they wrote in the previous lesson. The atmospheric carbon concentration of the classroom will be measured as a baseline. Students will make observations about the visual appearance of their algae farm.

Background

Before the Activity

- It is ideal for this lesson to be on a Friday or during the last class of the week. This way, the algae farms can sit over the weekend to reduce atmospheric carbon and students will see a bigger change in values when they measure carbon again during the next class.
- Ensure that there are enough tubes of each algae strain based on what each group decided to use in their design.
- Prepare the lids of the algae farm bins for the atmospheric carbon sensor.
    - Students will measure atmospheric carbon by inserting the atmospheric carbon sensor into their bin through a hole in the lid.
    - Make a hole in the middle of each lid that is just larger than the diameter of the carbon sensor.
    - Cover the hole with duct tape for now.

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Try). Say:** *So far, we have defined the problem with help from our client, learned relevant information, and brainstormed ideas for our algae farms.* Point out the “Problem” block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the “Try” stage.

Activity

3. **Gather into pre-determined design teams. Say:** *Today, you are going to use the Standard Operating Procedure, or SOP, that you wrote to construct your algae farm.*
4. **Hand out Duplication Master 8.A Data and Observations. Say:** *We will be tracking different characteristics of your algae farms to see how they change over time. Today, you will record the baseline atmospheric carbon concentration and information about how your farm looks.*
5. **Measure the current atmospheric carbon level as a baseline.** Ensure that all students are wearing latex gloves and safety glasses. Instruct students to gently lift the duct tape and insert the atmospheric carbon sensor into the bin. Once the sensor has settled on a number, it should be recorded in 8.A Data and Observations. Ensure that students reapply the duct tape so the lid is airtight.
6. **Allow students time to build their algae farms.** Students should follow the procedure they wrote during the previous class. The general procedure should be:
    - Add barriers to the bin if students would like to keep strains separate.
    - Prepare the saltwater concentration(s) you would like to use.
    - Add the algae to the bin.
    - Put your algae in a teacher-approved area of the classroom that you would like depending on how much light you would like to have on your farm.
7. **Make observations about your algae farm.** Have students fill out the visual observation portion of 8.A Data and Observations. Students should also provide a general sketch of their algae farm.

Closure

8. **Connect the activity to the engineering design challenge. Ask:** *What did we learn today that will help us provide a recommendation to the client? How will our activity today prepare us to make the best possible recommendation to the client?* **Say:** *We will move to the Test stage during our next class.*

Duplication Masters

8.A Data and Observations

Name____ Date_______________ Period __________

8.A Data and Observations

Baseline Atmospheric Carbon Concentration: ________________ ppm

Visual Observations:

What does the algae look like in the water? What color is it? How much space does it take up? Is it moving or still? Write down anything you think may be important.

Algae Farm Sketch

Sketch the general construction of your algae farm. If you have different strains, ensure you label which strain is where within your farm. Include any barriers.

Name____ Date_______________ Period __________

LESSON NINE:

Lesson Objectives
Students will be able to:
- Collect atmospheric carbon data

Time Required
One 50-minute lesson

Materials
Per classroom
- EDP Poster
- Vernier CO_2 Gas Sensor
- Vernier LabQuest 3

Per group (3 per group)
- Constructed algae farm

Per student
- EDP slider and paperclip
- Laptop/Chromebook/ Tablet
- Engineering notebook
- Pencils and erasers
- Latex gloves
- Safety glasses

Standards Addressed
- NGSS: HS-ETS1-3

Key Terms
Algae farm, atmospheric carbon, data collection

Lesson Summary
Students will measure the atmospheric carbon levels within their algae farms to determine if it has successfully reduced over time. Design teams will then critically think about their design and decide what its pros and cons are.

Classroom Instruction
Introduction
1. **Tie in the engineering problem. Ask:** *What is our engineering design problem?*
2. **Identify where they are in the engineering design process (Test). Say:** *So far, we have defined the problem with help from our client, learned relevant information, brainstormed ideas for our algae farms, and physically constructed algae farms.* Point out the "Problem" block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the "Test" stage.

Activity
3. **Gather into pre-determined design teams. Say:** *Today, you are going to see if your algae farm has changed the atmospheric carbon concentration.*
4. **Hand out Duplication Master 9.A Data and Observations. Say:** *Today, we will be comparing your baseline data from last class to today's data and observations.*
5. **Make observations about your algae farm. Ask:** *Does your algae farm look the same as the last time you saw it? What is the same? What has changed? Write down your answers on the Data and Observation handout. Make a prediction about whether the atmospheric carbon concentration will have increased, decreased, or remained the same.*
6. **Measure the atmospheric carbon concentration.** Ensure that all students are wearing latex gloves and safety glasses. Instruct students to gently lift the duct tape and insert the atmospheric carbon sensor into the bin. Once the sensor has settled on a number, it should be recorded in 9.A Data and Observations. Ensure that students reapply the duct tape so the lid is airtight.

7. **Talk within design teams about the changes. Say:** *In your design teams, spend some time discussing what happened. Did your atmospheric carbon concentration decrease as you hoped? Why do you think it did or did not? What would you change if you could do the experiment again? Would you recommend this algae farm to the client?*

Closure

8. **Connect the activity to the engineering design challenge. Ask:** *What did we learn today that will help us provide a recommendation to the client?* **Say:** *We will move to the Decide stage during our next class.*

Duplication Masters

9.A Data and Observations

Name_______________________________________ Date_______________ Period ___________

9.A Data and Observations

Visual Observations

What has changed or remained the same? Has anything moved?

Predictions

Do you think your atmospheric carbon concentration will have increased, decreased, or remained the same? Why do you think this?

Baseline Atmospheric Carbon Concentration: ________________ ppm

Updated Atmospheric Carbon Concentration: ________________ ppm

Conclusions

Did your atmospheric carbon concentration decrease as you hoped? Why do you think it did or did not? What would you change if you could do the experiment again? Would you recommend this algae farm to the client?

Name______________________________________ Date______________ Period __________

LESSON TEN:

Lesson Objectives
Students will be able to:

- Communicate science, technology, engineering, and mathematics ideas by giving presentations
- Use evidence-based reasoning to support their engineering decisions

Time Required
Two 50-minute lessons

Materials
Per classroom

- EDP Poster

Per student

- EDP slider and paperclip
- Laptop/Chromebook/Tablet
- Engineering notebook
- Pencils and erasers

Standards Addressed

- NGSS: HS-ETS1-3

Key Terms
Criteria, constraint, decision matrix, communication, evidence-based reasoning

Lesson Summary

In this lesson, students will report out their group findings to provide a holistic, evidence-based recommendation to the client as a class. Students will prepare presentations as a team to share their design with the class. Students will review one another using the decision matrix prior to providing a final recommendation to the client.

Background

Teacher Background

In this lesson, students will be making presentations to convince the client that their algae farm is the best option, or if they recommend the client does not choose their algae farm. The teacher can choose from a variety of presentation options based on the materials and technology that are available. Presentations may be live, video recorded, or use any other technology resources available. Alternatively, the teacher may choose to have students write a letter to the client that includes the same information that would be included in the presentation. This lesson is structured to allow one class period for preparation and one for presentation and conclusion, but this should be adjusted to meet the needs of the class.

Before the Activity

- The teacher may choose to provide a presentation template to the students to save time, allowing them to focus more on content than on presentation aesthetics.
- Before distributing Duplication Master 10.E Client Memo 5, it is recommended that the teacher adds feedback specific to the students' presentations. If the teacher wants to do this, they will need to treat 10.E Client Memo 5 as a template and make a new version. They will add feedback specific to the students after the first sentence of the body of the letter.
- After students complete their presentations, the teacher will evaluate their designs based on the 10.B Client Communication Requirements document. NOTE: Although some students thrive on competition, it can have a negative impact on the engagement of other students. The teacher will need to decide on the level of competition based on their students.

Classroom Instruction

Introduction

1. **Tie in the engineering problem. Say:** *We are almost done with solving this engineering design challenge! Can anyone tell me about the problem? Who is our client? What problem do they want us to solve? What are the criteria and constraints of the problem?*
2. **Identify where they are in the engineering design process (Decide).** Point out the "Problem" block on the Engineering Design Process (EDP) poster and have students look at their EDP sliders. **Ask:** *What step of the engineering design process are we in?* The students should identify that they are in the "Decide" stage.

Activity

3. **Read Duplication Master 10.A Client Memo 4. Ask:** *What is the client asking us to do?* (Prepare a presentation and a written document to convince the client and the rest of the class which design is best.)
4. **Explain what needs to be included in the presentation.** Hand out Duplication Master 10.B Client Communication Requirements. Briefly describe what is required. Share the presentation options that are available to students. If the teacher has developed a template for students, they should distribute it now. Note that approximately six slides should be included in the presentations:
    a. Introduction of Students
    b. Problem Summary
    c. Importance of STEM education and student interest
    d. Summary of Design
    e. Test Results
    f. Recommendation to Client
5. **Prepare design review presentations. A**llow students time to finish preparing for their presentations (e.g., creating visuals, filming video, rehearsing scripts, etc.).
6. **Use the decision matrix to assess design recommendations.**
7. **Prepare a class report to the client.** This is the final deliverable which must include the formal recommendations to the client with scientific justification behind the choice.
8. **Identify where they are in the engineering design process (Communication). Ask:** *What stage of the engineering design process are we in now?* Facilitate a discussion about why communication with the client is vital to engineering design.

Assessment

Pre-Activity Assessment:
Class discussion about what is important in a presentation.

Activity Embedded Assessment:
Presentation planning sheet.

Post-Activity Assessment:
Final presentation assessed using 10.B Client Communication Requirements.

Duplication Masters

10.A Client Memo 4
10.B Client Communication Requirements
10.C Decision Matrix Directions
10.D Decision Matrix Activity
10.E Client Memo 5
10.F Content Post-Assessment

Educator Resources

10.G Content Post-Assessment Key

Students should identify that they are in the “Communicate” stage.

Closure

9. **Revisit engineering design challenge.** Discuss the client, the problem, what information led to their informed decision, and how criteria and constraints were included in the decision-making process.
10. **Provide feedback from the client.** Read Duplication Master 10.E Client Memo 5 as a class. Reflect on the engineering design process and how the process was used throughout the unit.
11. **Complete Duplication Master 10.F Content Post-Assessment.**
12. **OPTIONAL: Review the entire unit.** If time allows, the teacher may choose to review some of the material during the Learn lessons.

10.A Client Memo 4

Dear Engineers,

Thank you for your hard work in developing algae farms! As you finalize your decision, I would like each team to prepare a presentation describing your design, your evaluation of it, and whether or not you would recommend the design. This is your opportunity to convince the other design teams that your algae farm is the best, so please ensure you use the guidelines I have attached when preparing your presentation.

Each team should also prepare a written document with the same details as their presentation. This is your chance to convince ME that your design is the best!

Sincerely,

Cole Wattson

Cole Wattson
Environmental Engineer
REFINES (Reducing Emissions From INdustrial Energy Stacks)

10.B Client Communication Requirements

- Students introduce themselves.
- Students summarize the client's problem including criteria and constraints.
- Students explain why it is important to reduce carbon emissions
- Students describe their solution to the problem:
  - Describe the algae farm.
  - Explain the test results they found in lesson nine.
  - Provide a recommendation to the client about their design.
- Students show data and evidence gathered and used in their design.
- Students justify their decision using data and evidence.
- All team members have a role in the presentation.
- Students demonstrate in-depth knowledge of their algae farm.
- Include a point about environmental justice or climate justice.

10.C Decision Matrix Directions

A decision matrix is a tool that evaluates and prioritizes your options to help you make the best decision. The row represents your algae farm, which will be evaluated for each of the four column headings. The four column headings represent important factors to consider when making your recommendation to the client. For this decision matrix, each factor will be rated on a scale from 1 to 5. A rating of 1 indicates that the design does not meet expectations for the category, while a rating of 5 indicates that the design exceeds expectations for the category. An explanation of each category is given below.

Category	**Explanation**	**A rating of 1 indicates...**	**A rating of 3 indicates...**	**A rating of 5 indicates...**
Reduction of Atmospheric Carbon	*Was the algae farm successful at reducing the atmospheric carbon concentration?*	*Atmospheric carbon was not reduced.*	*Atmospheric carbon was reduced partially reduced.*	*Atmospheric carbon was very reduced.*
Algae Farm Cost	*How much did the farm cost?*	*The most expensive farm in the class.*	*The average cost for a farm in the class.*	*The least expensive farm in the class.*
Use of Evidence-Based Reasoning	*Did the presenters show data to back up their statements?*	*No data was provided.*	*Some evidence was provided, but it was not clear how it led to their decision.*	*Their decisions and recommendation were backed by atmospheric carbon data.*
Environmental or Social Justice is Addressed	*Did the presenters talk about either environmental justice or social justice?*	*Justice was not addressed.*	*Just was addressed, but it did not meet the definition of environmental or social justice.*	*Justice was addressed.*

10.D Decision Matrix Activity

Take notes while each group gives their presentation on their algae farm, paying specific attention to the presenters' comments on each of the four categories. Once the presentation is finished, rate the algae farm for each of the four categories on a scale from 1 to 5. Find the total score for each row. The row with the highest value is what you consider to be the best algae farm to recommend to the client based exclusively on these criteria.

Design Team	Reduction of Atmospheric Carbon	Algae Farm Cost	Use of Evidence-Based Reasoning	Environmental or Social Justice is Addressed	TOTAL SCORE

10.E Client Memo 5

Dear Engineers,

I received your presentations and final report this morning and have reviewed them. The design you recommended will be extremely helpful in reducing carbon emissions from the local power plant.

Thank you for your dedication to this engineering design challenge and for all of the hard work that you did for my company. I hope to have the opportunity to work with you again in the future.

Sincerely,

Cole Wattson

Cole Wattson
Environmental Engineer
REFINES (Reducing Emissions From INdustrial Energy Stacks)

Name____ Date_______________ Period __________

10.F Content Post-Assessment

1. List five steps of the carbon cycle.

2. How does a microelectronic sensor measure atmospheric carbon?

3. What is environmental justice?

4. How do carbon emissions negatively impact the environment?

5. Explain what happens during photosynthesis. Write the chemical equation for photosynthesis.

6. Explain cellular respiration and its purpose.

7. What does the term, “microelectronics” mean?

8. How are microelectronics used in the field of biology?

9. What jobs would you be interested in that use microelectronics?

10. Provide one example of how microelectronics is used in that job.

Name____ Date_______________ Period ___________

10.G Content Post-Assessment Key

1. List five steps of the carbon cycle.

   Correct answers include decomposition, sedimentation, soil respiration, combustion, respiration, photosynthesis, dissolution, diffusion, and human activity.

2. How does a microelectronic sensor measure atmospheric carbon?

   The sensor emits an infrared light that is absorbed by a receiver. A microchip then converts the absorption into a carbon concentration.

3. What is environmental justice?

   Environmental justice is the pursuing the belief that regardless of color, race, gender, socioeconomic status, religion, or anything else, every person has the right to a clean and healthy environment.

4. How do carbon emissions negatively impact the environment?

   Carbon is a greenhouse gas that increases the temperature of the earth, causing climate change.

5. Explain what happens during photosynthesis. Write the chemical equation for photosynthesis.

   During photosynthesis, the organism absorbs solar energy and uses carbon dioxide and water to produce chemical energy in the form of glucose (with oxygen as a byproduct).

   $6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O2$

6. Explain cellular respiration and its purpose.

   Cellular respiration is the process that breaks down glucose to produce ATP (energy). This is important so that the cell has energy to complete other processes, such as signaling, transport, and DNA and RNA synthesis.

7. What does the term, “microelectronics” mean?

   Student answers may vary, but the formal definition of microelectronics is the design, manufacture, and use of microchips.

8. How are microelectronics used in the field of biology?

   There are many answers to this question, but one example is microchips in sensors.

9. What jobs would you be interested in that use microelectronics?

   Students’ answers will vary based on interest. Credit may be given as long as at least one job example is provided.

10. Provide one example of how microelectronics is used in that job.

    Students’ answers will vary based on interest. Credit may be given as long as at least one example is provided of how microelectronics is used in the job they provided in question nine.