EngrTEAMS

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

Got GMOs?

Grades 6-8

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

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About EngrTEAMS

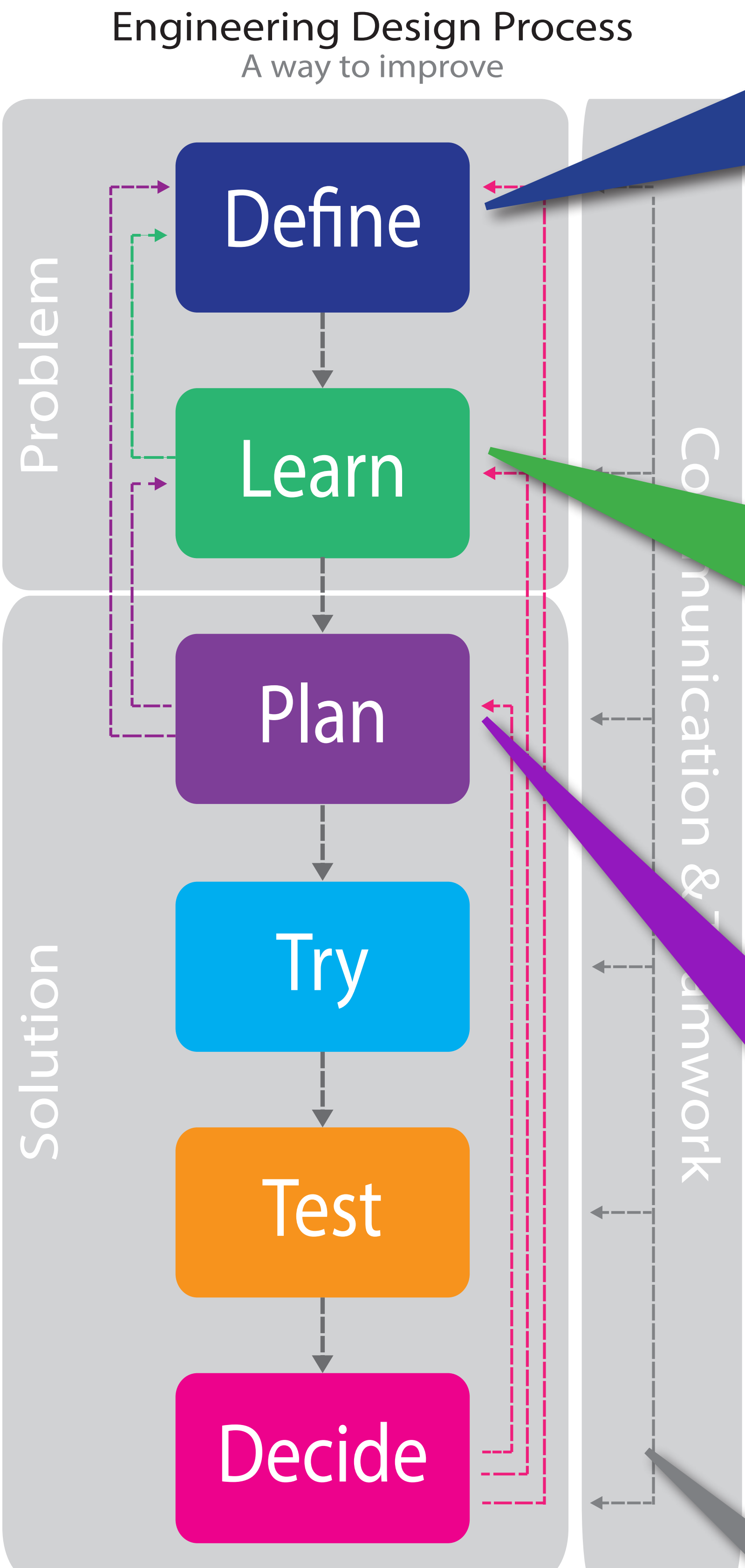
Purpose

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

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

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

Overview: Engineering Design Process



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

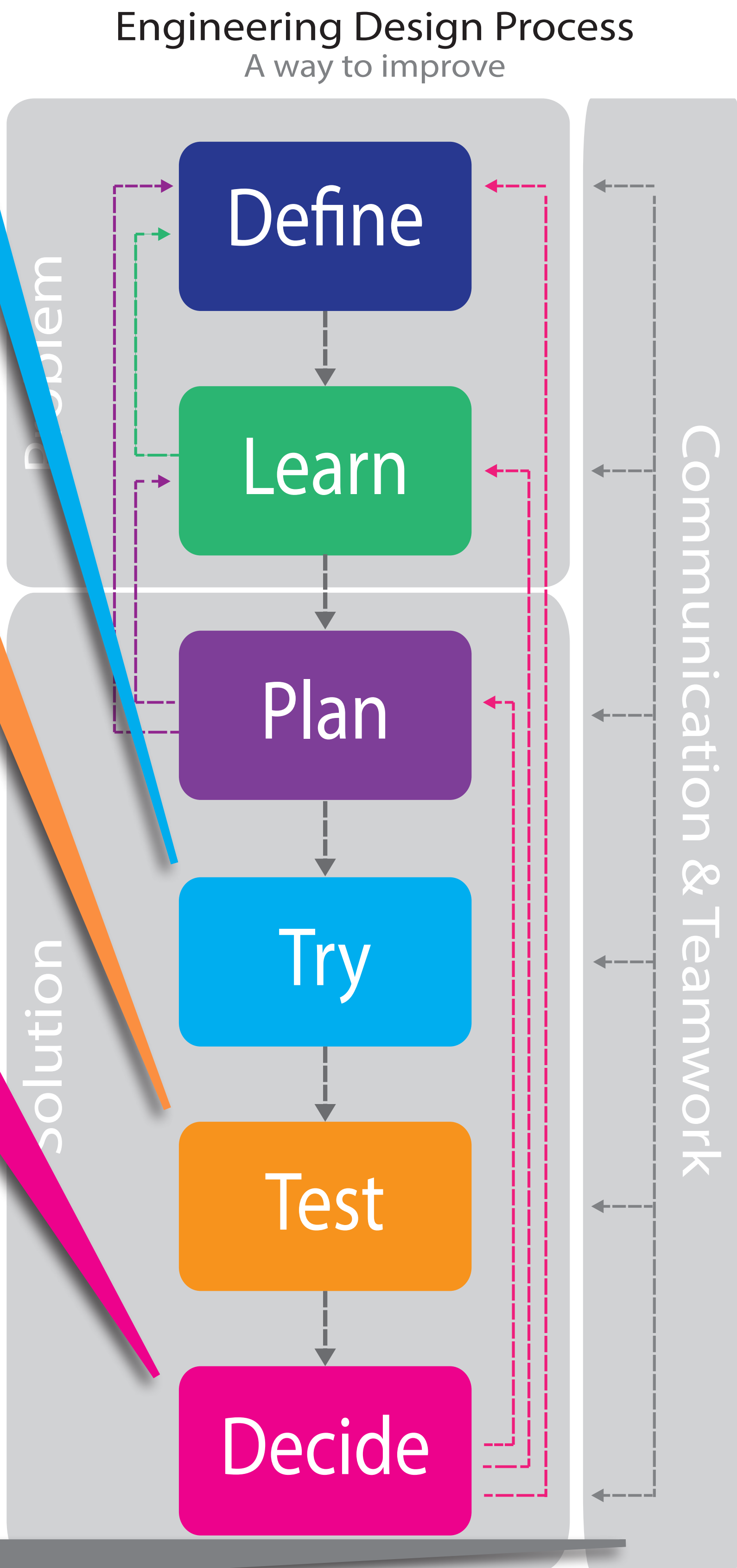
DECIDE IF THE SOLUTION IS GOOD ENOUGH

- 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



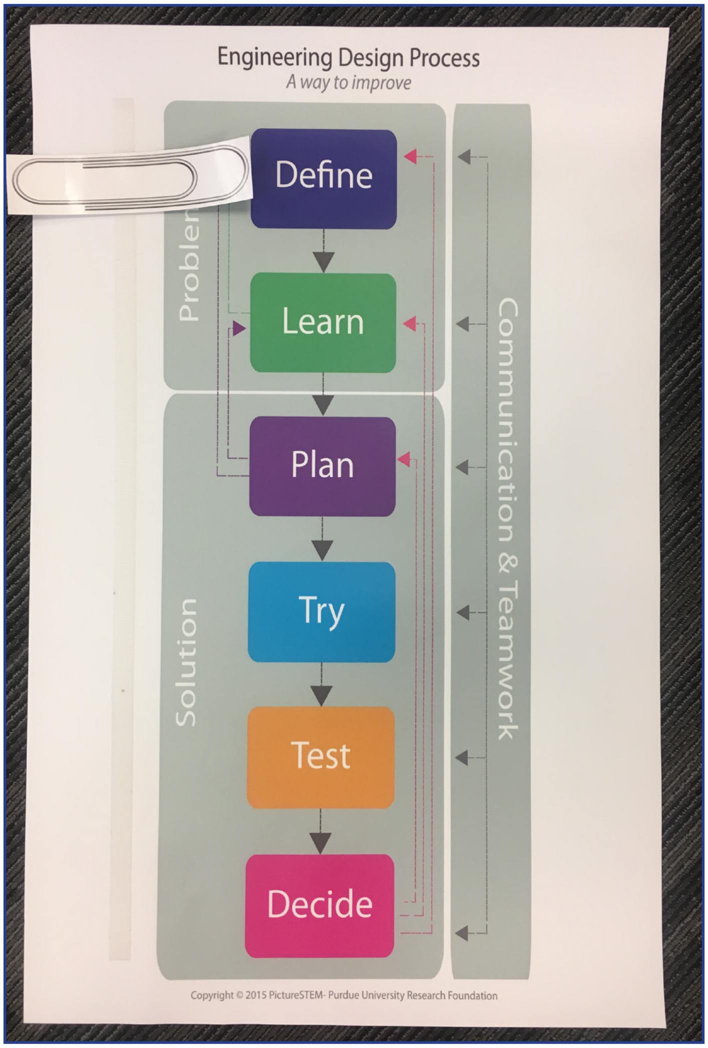
Overview: How to make EDP sliders

HOW TO CREATE THE POSTER

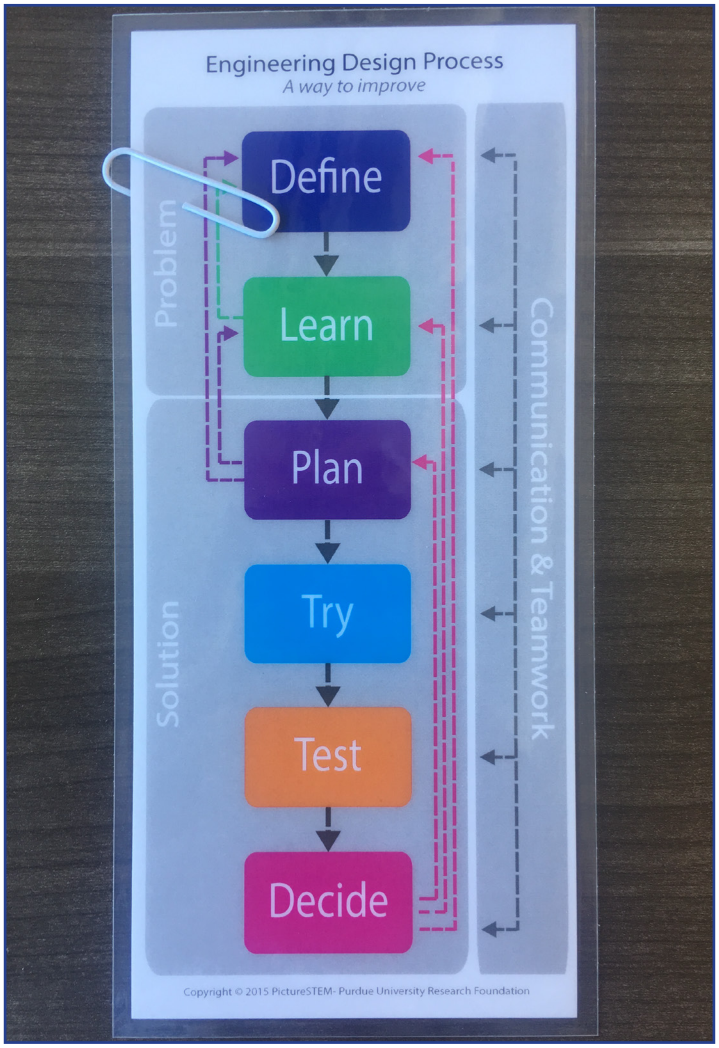
1. Download the high-quality PictureSTEM Slider Poster and the paper clip images from PictureSTEM.org.
2. Print the poster and the paper clip on poster-sized paper and cut to size. High-gloss or semi-gloss paper is the best choice.
3. Use self-sticking Velcro on the back of the paper clip and down the 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.

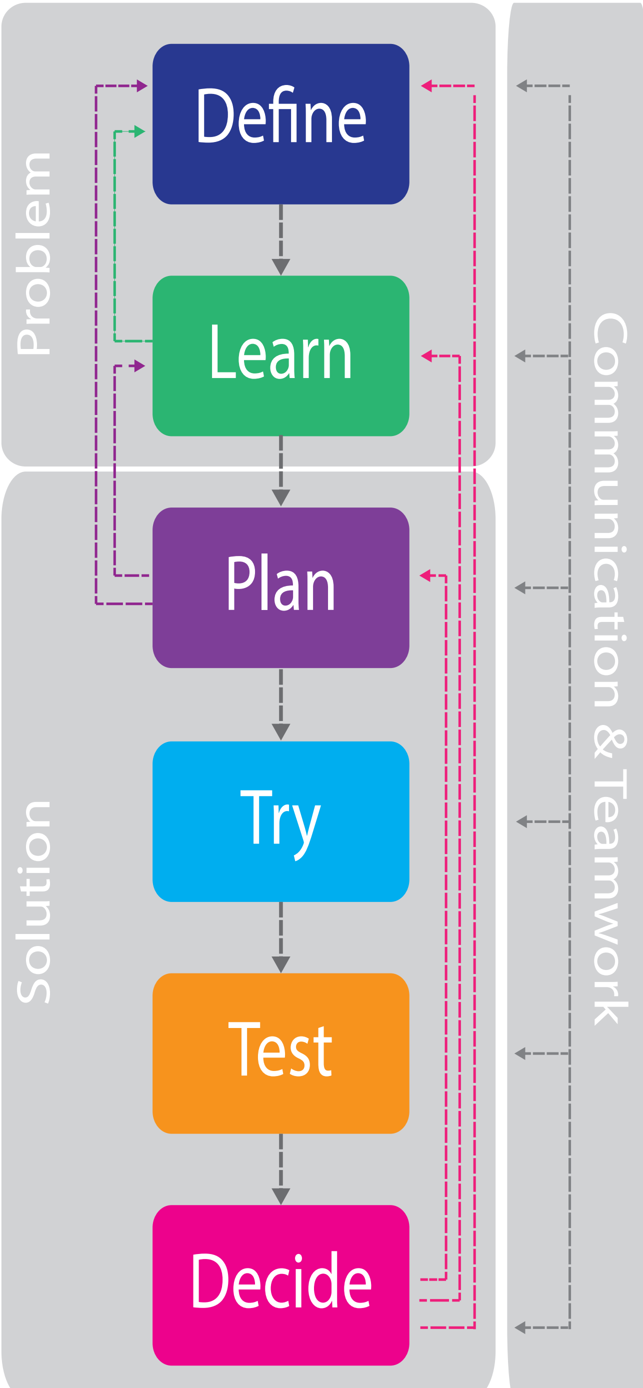


Poster

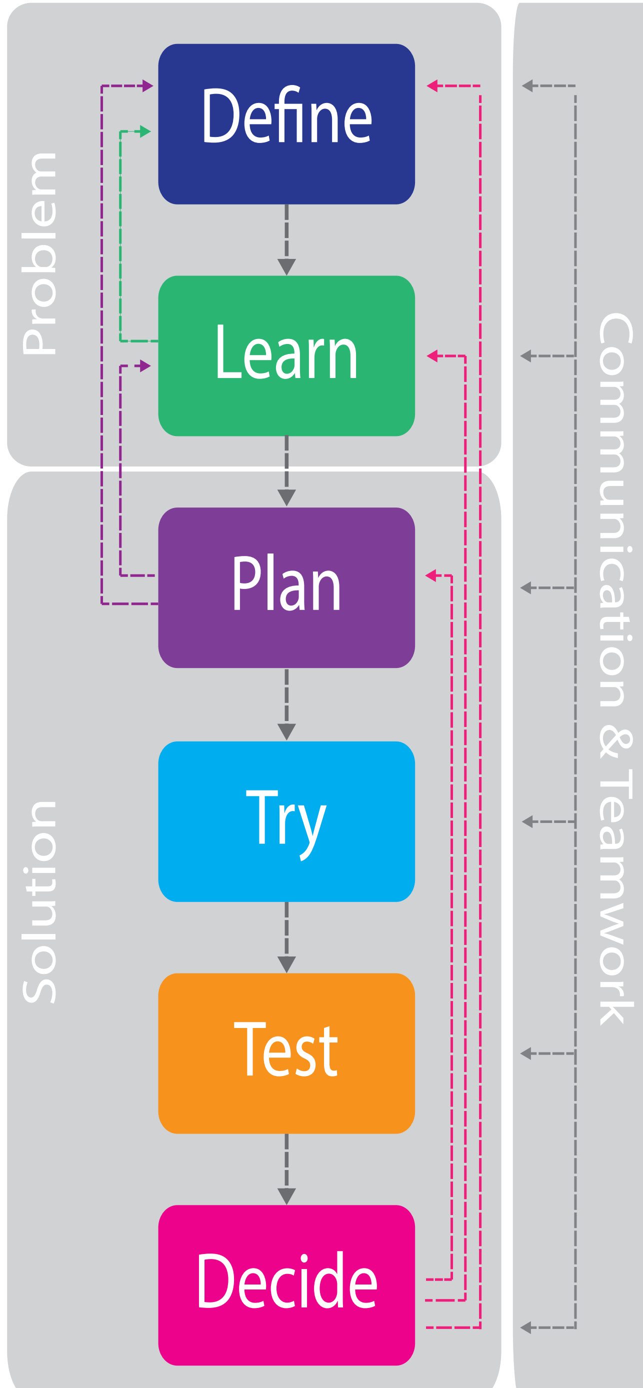


Individual slider

Engineering Design Process
A way to improve



Engineering Design Process
A way to improve



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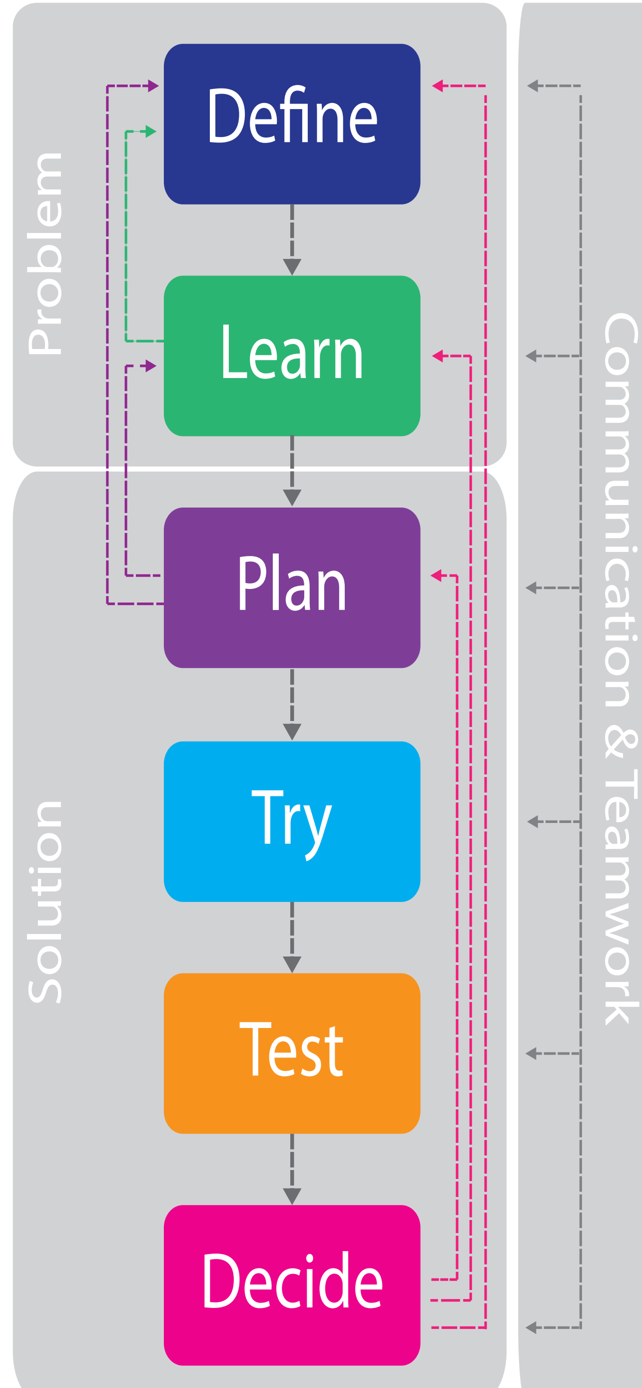
Engineering Design Process
A way to improve



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Overview: Unit Description

Grade Levels:

6-8

Approximate Time Needed to Complete Unit:

Sixteen 45-minute class periods

Unit Summary

In this unit, students are taught the mathematical and scientific concepts related to genetics through the incorporation of an engineering design challenge. At the outset of the unit, students are introduced to genetically modified organisms (GMOs) and the client, the University of Minnesota's Agricultural Department, who needs to determine if a new barrier effectively reduces cross-contamination of non-GMO corn fields from GMO corn fields. Students use what they know about genetics and heredity to develop a strategy to test for cross-contamination once this newly proposed barrier is installed. Designs for the unit are evaluated to assess the extent to which the experimental designs meet the specifications of the client and reliably test for cross-contamination. Finally, students write a final letter, including their designs and design justifications, to pitch their experimental design to the client.

Science Connections	Technology & Engineering Connections	Mathematics Connections
cells contain DNA which is where genes are located, genes carry information that determine the inherited traits of organism, in asexual reproduction all the genes come from a single parent, in sexual reproduction half of the genes come from each parent, some traits of organisms are inherited through environmental influences	understand ethical and practical uses of technology in scientific and engineering contexts, understand the process of engineering design, use engineering as a context in which to frame scientific learning	make generalizations about a population from a sample, use data to draw inferences about a population, gauge variation in estimates or predictions, understand probability and statistics

Unit Standards

Next Generation Science Standards

- **MS-LS1-1:** Conduct an investigation to provide evidence that living things are made of cells; either one cell or many different numbers and types of cells.
- **MS-LS1-2:** Develop and use a model to describe the function of a cell as a whole and ways the parts of cells contribute to the function.
- **MS-LS1-3:** Use argument supported by evidence for how the body is a system of interacting subsystems composed of teams of cells.
- **MS-LS3-2:** Develop and use a model to describe why asexual reproduction results in offspring with identical genetic information and sexual reproduction results in offspring with genetic variation.
- **MS-ETS1-1:** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

Overview: Unit Description

- **MS-ETS1-2:** Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- **MS-ETS1-3:** Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
- **MS-ETS1-4:** Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

Common Core State Standards - Mathematics

- **6.SP.B.5a:** Reporting the number of observations.
- **6.SP.B.5b:** Describing the nature of the attribute under investigation, including how it was measured and its units of measurement.
- **7.SP.A.1:** Understand that statistics can be used to gain information about a population by examining a sample of the population; generalizations about a population from a sample are valid only if the sample is representative of that population. Understand that random sampling tends to produce representative samples and support valid inferences.
- **7.SP.A.2:** Use data from a random sample to draw inferences about a population with an unknown characteristic of interest. Generate multiple samples (or simulated samples) of the same size to gauge the variation in estimates or predictions. *For example, estimate the mean word length in a book by randomly sampling words from the book; predict the winner of a school election based on randomly sampled survey data. Gauge how far off the estimate or prediction might be.*
- **7.SP.A.5:** Understand that the probability of a chance event is a number between 0 and 1 that expresses the likelihood of the event occurring. Larger numbers indicate greater likelihood. A probability near 0 indicates an unlikely event, a probability around 1/2 indicates an event that is neither unlikely nor likely, and a probability near 1 indicates a likely event.

Unit Assessment Summary

Throughout this unit, students individually maintain an engineering notebook to document their engineering design processes. In this, students make observations, collect data, and plan for their design. Part of the engineering notebook includes answering specific questions related to that day's activities. You may choose to post the questions on your overhead/PowerPoint slides, or give the students printed versions (included as duplication masters in each applicable lesson) to tape or glue into their notebooks. Students use their notebooks as a reference – a place to maintain the information they are learning through the design process. Additionally, students reflect on their work throughout the design process. This is important for modeling what real-life engineers do. **Collect the engineering notebooks at the end of each class.** You will use the notebooks to assess student learning through their design process. Provide feedback to students on their notebook responses - rubrics are provided. You are encouraged to assign points for responses in the engineering notebooks. **Provide feedback often - especially lessons for which rubrics are provided.**

- The notebook pages are often set up as handouts in each lesson. If you prefer to use notebooks without having students paste copied pages in them, there is an appendix at the end of this unit that includes notebook prompts and how to have students title each entry.
- The final summative piece of this unit requires students to communicate to the client recommending a design and justifying its success as a solution to the engineering problem.

Overview: Lesson Summaries

Lesson 1: Introduction to the Engineering Challenge

This lesson serves as an introduction to the engineering design process, the engineering challenge and the client, to give students a context within which to learn about genetics. The lesson begins with pre-assessment in whatever form the instructor prefers (kahoot, paper/pencil, survey, etc) to assess student's prior knowledge on genetically modified organisms (GMOs). Following a discussion on engineering and the engineering design process, students are presented a problem of preventing cross pollination and maintaining separation between GMO crops and non-GMO crops in farmers' fields from the University of Minnesota. Students are then given some background knowledge on GMOs and time to discuss their relevance in large and small teams. The lesson concludes with a reading, centered on the ethics of GMOs, followed by a class debate or discussion and individual reflection.

Lesson 2: Introduction to DNA Structure and Function

This lesson serves as an introduction to the structure and function of DNA. The first part of the lesson is an important assessment to identify any prior knowledge and misconceptions that the students have related to DNA. Then the lesson goes into a review of the cell and the location of genetic material in the nucleus with a modeling activity that will be done in teams. It is important that students understand where the DNA is in the cell and that every cell of all living things has DNA. The DNA extraction lab is to help build students understanding of the genetics needed for the engineering challenge by showing that they can actually get DNA out of cells from plants/food. Using strawberries, everyday materials, and a simple procedure, students see the DNA from the cells of something that they eat. The lesson ends with students using their T-chart started in the engineering challenge introduction to add questions, knowledge, or rearrange the sticky notes.

Lesson 3: Genes and Trait Expressions

This lesson builds on the previous lesson by connecting the structure and function of DNA to genes and trait expressions. Students experience a demonstration in which the expressed genetic trait of their tasting ability is explored. Students taste phenylthiocarbamide (PTC) strips and determine if they are "tasters" or "non-tasters." Then students discuss genes, alleles, and traits. Variegated yarn and beads are used as a visual aide for students to see and visualize genes on DNA. An exploration of heritable traits follows, in which students compare their own traits to those of their parents and their peers.

Lesson 4: Introduction to Heredity

This lesson serves as an introduction to heredity by focusing on reproduction and how living things inherit genetic material. The lesson uses stations to help students explore and learn about inheritance, asexual and sexual reproduction, as well as plant fertilization through pollination.

Lesson 5: Applied Heredity

This lesson serves as an introduction to heredity and probability of inheritance using Punnett squares. Start by reviewing reproduction and DNA inheritance. The main goal of the lesson is to get students to understand how alleles are inherited and understand how to answer a problem using probabilities of the genes and traits the offspring inherits.

Overview: Lesson Summaries

Lesson 6: Genetic Modification

This lesson serves as an introduction to basic genetic engineering. Students practice splicing a gene using a paper plasmid. They physically cut the plasmid using scissors to represent how restriction enzymes are used to cut DNA at specific sites. Then, they tape a length of paper DNA into the plasmid to reconnect it to represent how DNA at restriction sites come together. This activity will help students understand how GMOs are created.

Lesson 7: Designing a Solution

Students review the engineering challenge and use their knowledge of genes and heredity to brainstorm ideas on designs that describe how to prevent, sample and test whether GMO cross-contamination occurred. The challenge is to provide an accurate, reliable, and timely procedure that the farmers can utilize to assess cross-pollination. Students employ evidence-based reasoning as they choose their first prototype in order to justify all of their design decisions. They are then presented with a client letter that discusses the results of their testing strategy.

Lesson 8: Redesigning a Solution

Based on anaylsis of their initial designs, students work to improve and redesign their testing strategy, while incorporating the constraints of cost, reliability, and time. They then re-test and evaluate their new design, and decide which strategy is better.

Lesson 9: Communicate with the Client

Students choose their best design strategy and justify their decisions in a presentation to the client. After the presentation, the students receive feedback from the client on their designs. The unit closes with a unit review and summative assessment to review what students have learned.

Overview: Unit Overview

Lesson	Time Needed	**Objectives** The student will be able to:
1: Introduction to the Engineering Challenge	two 45-minute class periods	• identify the problem from a client. • define genetically modified organisms (GMOs), engineer, engineering, ethics, genetics, and heredity. • explain why GMOs are produced. • describe and debate the pros and cons of GMO organisms.
2: Introduction to DNA Structure and Function	two 45-minute class periods	• describe the location and function of DNA. • follow laboratory protocols and procedures to complete an experiment. • analyze the results of an experiment to draw conclusions.
3: Genes and Trait Expressions	two 45-minute class periods	• define gene, trait, genotype, phenotype, and allele. • describe the location of DNA and genes in an organism. • identify or label the structural components of DNA. • explain how genes are related to traits. • differentiate a trait as either inherited or environmentally-influenced or both. • explain the structure and function of genes.
4: Introduction to Heredity	two 45-minute class periods	• explain how genes and traits are inherited. • compare and contrast sexual and asexual reproduction. • identify organism that reproduce sexually or asexually. • examine and identify reproductive organs of a flower/plant. • explain how fertilization through pollination occurs.
5: Applied Heredity	two 45-minute class periods	• create a Punnett square to represent inheritance of traits. • analyze a Punnett square to calculate probability and make predictions. • calculate the probability of a particular trait being passed down to an offspring. • predict the traits that would be present in an offspring. • explain inheritance of dominant and recessive alleles.
6: Genetic Modification	two 45-minute class periods	• explain what a GMO is and how it is created. • explain how the properties of DNA can be used to identify GMOs.

Overview: Unit Overview

Materials	Duplication Masters & Educator Resources
• **Per classroom:** (1) package Post-its, Engineering Design Process poster • **Per team:** large Post-it poster paper • **Per student:** GMO Informational Handout, GMO Debate Article, engineering notebook, pencil, Engineering Design Process slider	**DUPLICATION MASTERS** • 1.a. Pre-Assessment • 1.b. Problem Scoping • 1.e. Client Letter • 1.f. GMO Debate Activity **EDUCATOR RESOURCES** • 1.c. Problem Scoping Section 3 Answer Key • 1.d. Problem Scoping Notebook Prompts Rubric
• **Per classroom:** sinks, towels, DNA extraction solution (water, dish soap, and salt), 90% ice cold rubbing alcohol, Engineering Design Process poster • **Per team:** (1) large transparent balloon, (1) small color balloon, 2 - 5 cm segments of dark color yarn, (1) plastic bowl, (10) colored beads, (1) strawberry, (1) Ziploc freezer bag, (1) transparent cup, 50 mL graduated cylinder, (1) 10 x 10 cm square of cheese cloth/coffee filter, rubber band, (1) craft stick, scissors • **Per student:** engineering notebook, pencil, Engineering Design Process slider	**DUPLICATION MASTERS** • **(Optional)** 2.a. Client Memo 1 • 2.b. Building a Model Cell • 2.c. DNA Extraction: Strawberry
• **Per classroom:** (2) pieces of variegated yarn, (4) colored page flags, Engineering Design Process poster • **Per team:** scissors, glue • **Per student:** (1) PTC tasting strip, engineering notebook, pencil, Engineering Design Process slider	**DUPLICATION MASTERS** • 3.a. Genetic Trait Activity
• **Per classroom:** corn pollination readings, Engineering Design Process poster • **Per team:** (1) flower • **Per student:** iPad or electronic devices, engineering notebook, pencil, Engineering Design Process slider	**DUPLICATION MASTERS** • 4.a. Reproduction Stations
• **Per team:** (6) 1-centimeter square cubes of 1 solid color (red), (6) 1-centimeter square cubes of 1 solid color (blue), Engineering Design Process poster • **Per student:** engineering notebook, pencil, Engineering Design Process slider	**DUPLICATION MASTERS** • 5.a. 3-D Punnett Square Activity • 5.b. Mendelian Genetics • **(Optional)** 5.c. Alien Genetics • 5.d. Genetics Practice Problems
• **Per classroom:** Engineering Design Process poster • **Per team:** scissors, glue • **Per student:** engineering notebook, pencil, Engineering Design Process slider	**DUPLICATION MASTERS** • 6.b. Gene Splicing **EDUCATOR RESOURCES** • 6.a. Gene Splicing Background

Overview: Unit Overview

Lesson	Time Needed	**Objectives** The student will be able to:
7: Designing a Solution	two 45-minute class periods	• work toward the solution of a problem using engineering. • develop and evaluate a plan acting as an engineer. • describe the tradeoffs of an engineered design. • justify why their solution is appropriate.
8: Redesigning a Solution	one 45-minute class period	• use previous knowledge to create an improved design. • work toward the solution of a problem using engineering. • develop and evaluate a plan acting as an engineer. • describe the tradeoffs of an engineered design.
9: Communicate with the Client	one 45-minute class period	• communicate their design through the use of evidence-based reasoning • justify why their design is appropriate.

Overview: Unit Overview

Materials	Duplication Masters & Educator Resources
• **Per classroom:** Engineering Design Process poster, chart paper • **Per student:** engineering notebook, pencil, Engineering Design Process slider	**DUPLICATION MASTERS** • 7.a. Client Memo 2 • 7.b. Planning Reflection Questions • 7.d. Modified Design Options • 7.e. Evidence-Based Reasoning • 7.j. Client Test Letters • 7.l. Test Solution Ideas **EDUCATOR RESOURCES** • 7.c. Planning Reflection Questions Rubric • 7.f. Evidence-Based Reasoning Rubric • 7.g. Evidence-Based Reasoning Instructions • 7.h. Teacher Observation Protocol: Try • 7.i. Detailed Design Options • 7.k. Teacher Observation Protocol: Test • 7.m. Test Solution Ideas Rubric
• **Per classroom:** Engineering Design Process poster • **Per student:** engineering notebook, pencil, Engineering Design Process slider	**DUPLICATION MASTERS** • 8.a. Assessment Rubric • 8.b. Detailed Design Options • 8.d. Assessment Rubric for Redesign • 8.e. Redesign Evaluation **EDUCATOR RESOURCES** • 8.c. Teacher Observation Protocol: Redesign • 8.f. Redesign Evaluation Rubric
• **Per classroom:** Engineering Design Process poster • **Per student:** engineering notebook, pencil, Engineering Design Process slider	**DUPLICATION MASTERS** • 9.b. Unit Reflection • 9.d. Unit Review • 9.e. Summative Assessment **EDUCATOR RESOURCES** • 9.a. Client Communication Rubric • 9.c. Unit Reflection Rubric • 9.f. Summative Assessment Answer Key

Master Material List

	Material	Lessons Where Material is Used
Per classroom	(1) package of post-its	1
	sinks*	2
	towels*	2
	DNA extraction solution (dish soap, salt, and water)*	2
	90% ice cold rubbing alcohol	2
	(2) pieces of variegated yarn	3
	(4) colored page flags*	3
	corn pollination readings*	4
	Engineering Design Process poster*	1, 2, 3, 4, 5, 6, 7
Per team	large post-it paper	1
(assuming 3 or 4	(1) large transparent balloon	2
students per team)	(1) small color balloon	2
	2 - 5 cm segments of dark color yarn	2
	(1) plastic bowl	2
	(10) color beads	2
	(1) strawberry*	2
	(1) Ziploc freezer bag	2
	(1) transparent cup	2
	(1) plastic funnel	2
	(1) 10 x 10 cm square of cheese cloth/coffee filter	2
	(1) craft stick	2
	(1) rubber band*	2
	scissors*	2, 3, 6
	glue*	3, 6
	(1) flower*	4
	(6) 1-centimeter square cubes in solid color (red)	5
	(6) 1-centimeter square cubes in solid color (blue)	5
Per student	GMO Informational Handout*	1
	GMO Debate Article*	1
	(1) PTC tasting strip*	1
	iPad or electronic device*	3
	pencil*	1, 2, 3, 4, 5, 6, 7
	engineering notebook*	1, 2, 3, 4, 5, 6, 7
	Engineering Design Process slider*	1, 2, 3, 4, 5, 6, 7

* required materials not included in the kit

LESSON 1

Introduction to the Engineering Challenge

Lesson Objectives

Students will be able to:

- identify the problem from a client.
- define genetically modified foods, engineer, engineering, ethics, genetics, and heredity.
- explain why GMOs are produced.
- describe and debate the pros and cons of GMO organisms.

Time Required

Two 45-minute class periods

Materials

Per classroom:

- (1) package Post-its
- Engineering Design Process poster

Per team:

- large Post-it paper

Per student:

- GMO Informational Handout
- engineering notebook
- pencil
- Engineering Design Process slider

Standards Addressed

- Next Generation Science Standards: MS-LS1-3, MS-ETS1-1
- Common Core State Standards - Mathematics: 7.SP.A.5

Key Terms

genetically modified organism (GMO), engineering, engineer, genetics, ethics

Lesson Summary

This lesson serves as an introduction to the engineering design process (EDP), the engineering challenge and the client, to give students a context within which to learn about genetics. The lesson begins with pre-assessment in whatever form the instructor prefers (kahoot, paper/pencil, survey, etc) to assess student's prior knowledge on genetically modified organisms (GMOs). Following a discussion on engineering and the engineering design process, students are presented a problem of preventing cross pollination and maintaining separation between GMO crops and non-GMO crops in farmers' fields from the University of Minnesota. Students are then given some background knowledge on GMOs and time to discuss their relevance in large and small teams. The lesson concludes with a reading, centered on the ethics of GMOs, followed by a class debate or discussion and individual reflection.

Background

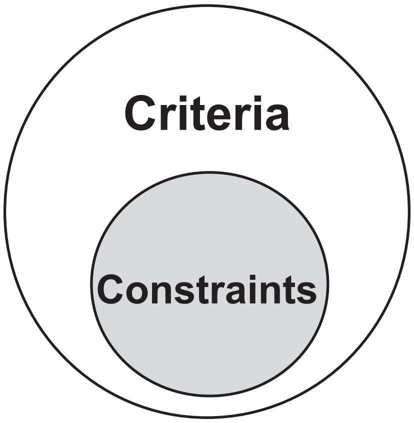
Teacher Background

This lesson will help students gain a basic understanding of GMOs and genetics, as well as getting them to begin thinking about the engineering design process in order to work toward a solution to the engineering challenge. A genetically modified organism (GMO) is any organism whose genetic material (DNA) has been altered using genetic engineering processes (gene guns, electroporation, vectors, and microinjections). The goal of this modification is typically to introduce a new trait to the organism that does not naturally occur in the species. These methods are often used for food crops to help create resistance to chemicals, pests, diseases, and environmental conditions. Genetic engineering can also yield crops with better nutrient profiles and reduce spoilage rates. For the past two decades, the use of GMOs by farmers has increased substantially. Most scientists agree that there is no increased risk to the health of the consumer from eating genetically modified crops, but there is some dissension amongst teams about the impact of genetically modified crops on the environment. There are also several ethical concerns related to food distribution throughout the world and economic property rights to GMOs. Furthermore, the trend of many countries' citizens to prefer non-GMO food sources is creating a demand among farmers for strategies to maintain pure crops (either GMO or non-GMO), while preventing cross-contamination of fields by the other. This desire is resulting in the design of many strategies to help farmers maintain an effective separation between GMO and non-GMO crops. This engineering design project will encourage students to think and work like engineers. It is designed to help the students utilize the information they gathered through their scientific experiments and instruction in order to design a method of testing to determine if there is any cross-contamination of non-GMO and GMO fields with one another. Genetics is the study of how traits are passed on from parent to offspring. An understanding of heredity (the passing of traits from parents to offspring) will be essential to complete the tasks and accomplish these learning goals related to the life sciences.

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, or "teams" of 3 or 4 throughout the unit. Effective teamwork is essential in this unit as well as in engineering in general; however, this unit does not provide specific support to develop those skills. If students do not have experience with teamwork, targeted team-building activities are highly recommended prior to beginning this unit.

Engineering design process: Students should have some familiarity with the engineering design process before beginning the unit. If they do not, the teacher will need to spend additional time explaining it, so this lesson may take more than one day. 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 not one scientific method. However, the various engineering design processes have similar components. The engineering design process (EDP) is an iterative process that 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 a 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 the front matter section about it.

Criteria and constraints: One difficulty students might have 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 the 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.



Cost is a common example of something that can be a criterion and a constraint. If the client requires engineers to stay within a specific budget, then this budget is a constraint. Any design solution that requires more money than the budget is automatically disqualified from being a quality solution. However, cost is also a relative criterion. Multiple design solutions that stay within the budget can be proposed. The costs of these solutions could be compared as one factor to determine which of the solutions is preferable.

Assessments

Pre-Activity Assessment
Assess students prior knowledge by listening to their responses to: *What do engineers do? How do engineers solve problems? What is a GMO? How are GMOs related to genetics?* Use students' answers to the *1.a. Pre-Assessment* as a baseline data about the students' current level of understanding and background knowledge.

Activity Embedded Assessment
Observe students' and teams' discussions and written responses to *1.b. Problem Scoping.* Check students' lists on their T-charts to see if the students can identify the content questions that they will be expected to master by the end of the unit.

Post-Activity Assessment
Use the *1.d. Problem Scoping Notebook Prompts Rubric* to evaluate students answers to the notebook prompts. Throughout the debate, evaluate students' level of understanding and evidence based reasoning skills. Check students' revised T-charts to see if they learned any of their desired knowledge.

DUPLICATION MASTERS
- 1.a. Pre-Assessment
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- 1.f. GMO Debate Activity

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- 1.d. Problem Scoping Rubric

Introduction to the Engineering Challenge

Some common misconceptions about the EDP:

- 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.
- 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 engineers are done with a project, they never think about it again.
    - **In reality:** A project is never really "done," and engineers often continue to improve and make changes.

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. Students' engineering notebooks will support their communication of ideas and should be used consistently throughout the unit. A number of worksheets are provided as duplication masters. If these worksheets are printed for students, they should be taped or stapled into their engineering notebooks so all of the unit information is stored within the notebooks.

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 or picture.

Additionally, the class could maintain a word wall.

Before the Activity

- Make copies of the GMO information handout (1 per student). Available at: https://cdn.shopify.com/s/files/1/0089/1562/files/GMO-Fact-sheet.jpg?1680.
- Cue up the videos on GMO cross-pollination for the debate activity. Available at: https://www.youtube.com/watch?v=1qw_5i9Gbw8 and https://www.youtube.com/watch?v=8z_CqyB1dQo.
- Determine student teaming method for the engineering teams. Ideally, these should be teams of 3 or 4.
- Make copies of the duplication masters (1 per student). NOTE: See pages 126-128 for instructions for using notebooks for the reflection prompts rather than duplication masters.
- Assmble the EDP individual sliders and post and EDP poster in the classroom (see the front matter for how to assemble).
- **(Optional)** Prepare the pre-assessment activity in the form of a survey, kahoot, etc. using the questions on *1.a. Pre-Assessment* if you do not want students to do the pre-assessment with pencil and paper.

Classroom Instruction

Introduction

1. **Review prior knowledge.** Lead a discussion with the class in which the students are able to share their prior knowledge on the topics of engineering, genetics, heredity, genetic engineering, and GMOs. Prompts may include the following: *What do engineers do? How do engineers solve problems? What is a GMO? How are GMOs related to genetics?*

2. **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 genetics, heredity, genetic engineering, and the engineering design process. Using the question on the *1.a. Pre-Assessment,* distribute hard copies or have students respond to the survey*.* Make sure to tell students that this just to assess any prior knowledge, so it is okay to not know the answers. NOTE: This is the same as the *9.e. Summative Assessment* that is completed at the very end of the lesson. Refer to the *9.f. Summative Assessment Answer Key* for the answers.

3. **Set up engineering notebooks.** Direct students to take out their engineering notebooks. Explain to the students that they will be using their notebook, to record their ideas for the engineering challenge. Guide them through making a table of contents on the first page.

4. **Complete problem scoping section 1.** Distribute the *1.b. Problem Scoping* worksheets. **Say:** *In this unit, we are going to be working on an engineering challenge. Before we get started, you're going to respond to some prompts about engineers and what they do.* Direct students to respond to the section 1 prompts.

5. **Form teams.** After students have finished the prompts, explain that 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.** Define engineering and engineers and take some notes on the engineering design process for students to place in their notebooks.

7. **Introduce the engineering design process.** Display the Engineering Design Process poster and pass out Engineering Design Process sliders 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.*

8. **Introduce the problem.** Read the *1.e. Client Letter* aloud using a reading strategy like "marking the text" to note vocabulary and important details. Students can then write in their notebooks any important information they hear in the letter. Give students time to discuss in small teams what information they heard in the letter. **Ask:** *What is the challenge? What are some possible constraints and criteria?*

9. **Identify the problem from the client.** Have the students reread the letter, if necessary, to identify the problem and write the problem in their notebooks.

10. **Sort information from the client letter.** Have the students work together to create a list of "required information" in order to help the client with his/her request. Students should write all of their items from the list on Post-its and make a T-chart. One side of the T-chart will be things that they "already know" and the other side will be the things that they "need to know". As they learn through the process, the students will move the Post-its over to the "already know" side. Hopefully all of the post-its will moved over to the "already know" side before they begin to plan.

11. **Complete problem scoping section 2.** After reading the letter, direct students to respond to the section 2 prompt on the *1.b. Problem Scoping* worksheet. They can do this individually or in teams.

12. **Complete problem scoping section 3.** After students have completed the section 2 prompt, direct students to section 3 of *1.b. Problem Scoping.* **Say:** *You are going to fill out this section of the worksheet using the information you have acquired from the client letter at this point. First, you'll fill in your individual responses to each prompt, then you'll work with your team to add your team responses. Remember that the client is the company who contacted us to do this work. The end users are the people who will actually*

end up using the product you design. Remind the students that they will continue to learn more about the challenge throughout the unit. Have students fill out this section individually, then discuss their responses with their teams and revise their answers.

13. **Gather information on GMOs.** Distribute copies of the GMO Informational Handout to students (available at: https://cdn.shopify.com/s/files/1/0089/1562/files/GMO-Fact-sheet.jpg?1680). Once students finish reading the handout, show them the two videos about the advantages and disadvantages of GMOs (available at: https://www.youtube.com/watch?v=1qw_5i9Gbw8 and https://www.youtube.com/watch?v=8z_CqyB1dQo). This will provide them with some initial content exposure.

14. **Discuss the GMO information.** Facilitate a discussion or note taking about the handout and videos about what the students learned. Be sure to address any misconceptions at this time, as many students may already have biases for or against GMOs. **Ask:** *How do the views of the teams differ? How do you determine fact from opinion?* Lead the students to identify relevant information from the videos as it relates to the client's request. Guide students to ask questions about the information presented in the videos. Have students summarize in their notebook and define GMOs, as well as ask questions.

15. **Set up a classroom debate.** Have the classroom split into teams for the discussion. Distribute *1.f. GMO Debate Activity*, and assign teams the roles in the activity. A debate format is possible, but he format of the discussion is up to your discretion. Ensure that each student contributes and feels comfortable contributing to the discussion. Then, the students should return to their small teams to reflect on the discussion and record important discussion points in their engineering notebooks. They should also make a final argument about the ethics case in their notebooks with justification on their stance.

Closure

16. **Revisit the problem.** Have the students revisit their list of questions or required information they composed for the engineering design challenge. The students should work with their small teams to make changes or adjustments to their lists. They can add new information that they'd like to receive from the client. They can move any information that they now feel they know. Have the students form an opinion on the question, *Will you or won't you try to buy non-GMOs?* and summarize it in their notebook. **(Optional)** Students can write a poem, song verse or design a t-shirt that states their opinion.

17. **Discuss the engineering design process. Ask:** W*hich phase of the engineering design process did we focus on related to our design challenge today? How do you know?*

Name________________________________ Date___________ Period _____

1.a. Pre-Assessment (1/2)

1. Which type of molecule contains genetic information that is passed from parents to offspring?
   a. fat molecules
   b. DNA molecules
   c. protein molecules
   d. carbohydrate molecule

2. What is a gene?
   a. a unit of information that determines the traits of an organism
   b. part of the chloroplast involved in photosynthesis
   c. where an organisms gets its resources
   d. protects the cell from bacteria

3. Humans, dogs, and trees are all living things. In which of these organisms would you find DNA molecules?
   a. only in humans
   b. only in humans and dogs
   c. in humans, dogs, and trees
   d. DNA molecules are not found in any of these organisms

4. Which of the following represents the correct order from smallest to largest? The smallest should be listed first.
   a. an atom, a chromosome, a cell
   b. an atom, a cell, a chromosome
   c. a cell, an atom, a chromosome
   d. a cell, a chromosome, an atom

5. Which of the following could be affected by the information in the DNA molecules of an organism?
   a. Both an organism’s physical characteristics and the function of the organism’s cells.
   b. An organism’s physical characteristics, but not the function of the organism’s cells.
   c. The function of the organism’s cells, but not the organism’s physical characteristics.
   d. Neither an organism’s physical characteristics nor the function of the organism’s cells.

6. Where are DNA molecules found in an animal’s body?
   a. Inside all types of cells in an animal’s body.
   b. Inside an animal’s body, but not inside any cells in an animal’s body.
   c. Inside sex cells, but not inside any other types of cells in an animal’s body.
   d. Inside blood cells, but not inside any other types of cells in an animal’s body.

7. Twins are born. One is a boy and one is a girl. Which statement is correct about their genetic makeup?
   a. The boy and the girl inherit genetic material from the father only.
   b. The boy and girl inherit genetic material from the mother only.
   c. The boy and girl inherit genetic material from both parents.
   d. The boy inherits genetic material from the father only and the girl inherits it from the mother only.

Name__________________________________ Date____________ Period _____

1.a. Pre-Assessment (2/2)

8. Which of the following supports the claim that the environment can affect genetic traits?
   a. trees get taller as they grow
   b. flower color varies with soil pH
   c. plants are self pollinating
   d. pine trees bear cones every other year

9. Which of the following is an internal compartment that houses the cell's DNA?
   a. lysosome
   b. nucleus
   c. ribosome
   d. cell membrane

10. A mouse's tail gets caught in a mouse trap. When the mouse pulls free, its tail gets cut off. If the mouse has babies later, how will this affect the length of the tails of its babies?
    a. It will affect the length of the tails of all the babies.
    b. It will affect the length of the tails of some of the babies.
    c. It will not affect the length of the tails of any of the babies.
    d. It depends on how old the mouse was when its tail was cut off.

LESSON 1

Name________________________________ Date___________ Period _____

1.b. Problem Scoping (1/3)

Section 1

Directions: Please answer the following questions.

1. What do engineers do?

2. How do engineers solve problems?

Section 2

Directions: Please answer this question after hearing about the engineering challenge

3. What are at least 3 questions that you want to ask the client? Ask questions that will help you understand the problem better. Make sure to ask about all important aspects of the problem.

Name___________________________________ Date____________ Period _____

1.b. Problem Scoping (2/3)

Section 3

Directions: Please answer the following questions after you have been able to ask questions about the challenge.

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

4. Who is the client?

   My response:

   Team response:

5. What is the client's problem that needs a solution? Explain why this is important to solve. Use information from your client to support your reasons.

   My response:

   Team response:

6. Who are the end-users?

   My response:

   Team response:

Name________________________________ Date___________ Period _____

1.b. Problem Scoping (3/3)

7. What will make the solution effective (criteria)? Use detailed information you have from the client.

   My response:

   Team response:

8. What will limit how you can solve the problem (constraints)? Use detailed information you have from the client.

   My response:

   Team response:

9. Think about the problem of GMO cross contamination. In terms of determining if a non-GMO plant has been contaminated, what are at least 2 things you need to learn in order to designing a testing procedure for cross-contamination? Make sure to consider all important aspects of the problem. Be specific.

   My response:

   Team response:

1.c. Problem Scoping Section 3 Answer Key

Section 3

4. **Who is the client?**

   James Randolf of the University of Minnesota Agricultural Department

5. **What is the client's problem that needs a solution? Explain why this is important to solve. Use information from your client to support your reasons.**

   He is asking for help to develop a new method to test whether GMO cross-contamination occurred in the corn fields. The organic farmers need to ensure they can maintain their organic and non-GMO certification.

6. **Who are the end-users?**

   Organic corn farmers

7. **What will make the solution effective (criteria)? Use detailed information you have from the client.**

   An effective, reliable and timely method to test whether cross-contamination occurred.

8. **What will limit how you can solve the problem (constraints)? Use detailed information you have from the client.**

   What scientific principles and methods students learn to test cross-contamination. Time, reliability and money restraints on testing procedures.

9. **Think about the problem of GMO cross contamination. In terms of determining if a non-GMO plant has been contaminated, what are at least 2 things you need to learn in order to designing a testing procedure for cross-contamination? Make sure to consider all important aspects of the problem. Be specific.**

   Answers will vary from student to student.

LESSON 1

Student Name________________________ Date__________ Period _____

1.d. Problem Scoping Rubric

Problem	Question	Learning Objectives	Rubric	
1.a.3	What are at least 3 questions that you want to ask the client? Ask questions that will help you understand the problem better. Make sure to ask about all important aspects of the problem.	Ask a variety of relevant questions to better understand problem.	**Asked at least 3 questions** CIRCLE: 0 1 2 3 4+	
			At least 3 questions are relevant to the problem CIRCLE: 0 1 2 3 4+	
			Considered at least 2 different aspects of the problem CIRCLE: 0 1 2 3 +	
1.a.4	Who is the client?	Identify the client.	yes no	**Correctly identified the client**
1.a.5	What is the client's problem that needs a solution? Explain why this is important to solve. Use information from your client to support your reasons.	Explain the problem based on a synthesis of information.	yes no	**Identified problem**
		Explain why the problem is important to solve based on evidence that is relevant to the problem.	yes no	**Explained why the problem is important**
			yes no	**Provided rationale from client information**
1.a.6	Who are the end-users?	Identify a specific and relevant end user.	yes no	**Correctly identified at least 1 end user**
1.a.7	What will make your solution effective (criteria)? Use detailed information you have from the client.	Explain criteria based on given information.	yes no	**Identified at least 1 criterion**
			yes no	**Connected information from client to criteria**

LESSON 1

Student Name______________________ Date__________ Period _____

1.d. Problem Scoping Rubric

Problem	Question	Learning Objectives	Rubric	
1.a.8	What will limit how you can solve the problem (constraints)? Use detailed information you have from the client.	Explain constraints based on information.	yes no	**Identified at least 1 constraint**
			yes no	**Connected information from client to constraints**
1.a.9	Think about the problem of GMO cross contamination. In terms of determining if a non-GMO plant has been contaminated, what are at least 2 things you need to learn in order to designing a testing procedure for cross-contamination? Make sure to consider all important aspects of the problem. Be specific.	Explain the background knowledge needed to develop a solution.	**Identified at least 2 topics they needed to learn** CIRCLE: 0 1 2 3 +	
			Topics are relevant to the problem CIRCLE: 0 1 2 3 +	
			Considered at least 2 different aspects of the problem CIRCLE: 0 1 2 3 +	

Notes:

LESSON 1

Name________________________________ Date____________ Period _____

1.e. Client Letter

Dear Student Engineers,

Genetically modified organisms (GMOs) are found prominently in Minnesota and throughout the world. More than ¾ of all common food crops found in grocery stores and farms are genetically modified. Often, these genetic modifications are done in order to create crops that are resistant to herbicides, pesticides, and other potentially harmful environmental conditions or to increase crop yield.

Many food suppliers in Minnesota want to be able to provide an alternative to GMO products by purchasing crops from farmers who grow non-GMO (organic) crops in their fields. These food suppliers wish to provide consumers with the opportunity to consume natural and unmodified food products. In order to provide food suppliers with certified organic crops, the organic farmers must follow some strict regulations from the United States Department of Agriculture (USDA) to ensure that their crops are not contaminated by GMOs.

In Minnesota, a large proportion of organic farms are growing corn. These organic corn farmers have been working hard to maintain their organic designation so they can continue to sell their crops to organic food suppliers. The number one threat to GMO contamination of non-GMO farms is the spread of pollen, which can be transferred from GMO crops to non-GMO crops. The livelihood of these farmers depends on their ability to prevent and assess whether cross-pollination of their organic crops occurred.

These farmers are seeking help from the University of Minnesota Agricultural Office to develop a plan that describes how to prevent, sample and test whether cross-contamination occurred in their fields so farmers can maintain their organic and non-GMO certification. We are at capacity in our ability to keep up with all of the work in the area of GMOs that is coming our way. I want to enlist your help to provide us with a process for this workbook.

Please use the engineering design process, science and mathematics knowledge, and your ingenuity to develop a process for us. Please also provide us with evidence of why your design is the one we should move forward with. Please note that this method must be timely, reliable, cost-effective and demonstrate the use of scientific reasoning. We are looking forward to seeing what you develop.

Sincerely,

James Randolf

James Randolf

Organic Outreach Coordinator

University of Minnesota, Agricultural Department

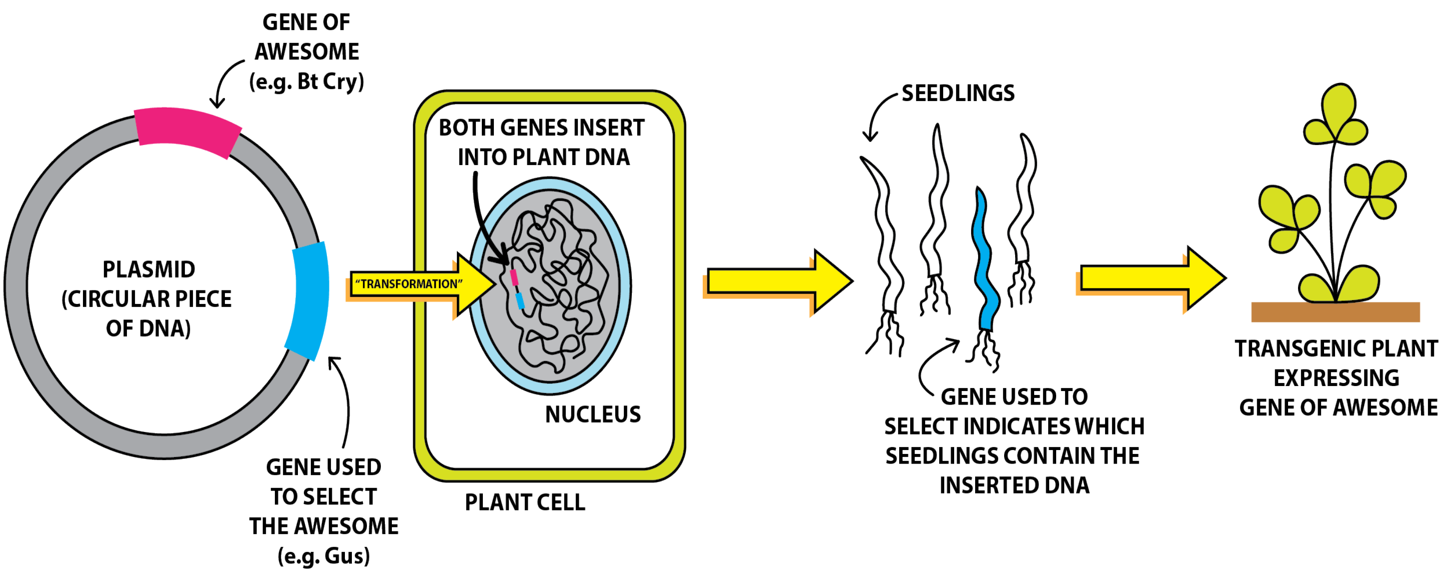
LESSON 1

Name________________________________ Date___________ Period _____

1.f. GMO Debate Activity (1/2)

The Task: You will participate in a debate where each team will be assigned a role to play during this exercise.

The Issue: Farmers are growing genetically modified (GM) crops on thousands of acres in the U.S. Over 80% of all processed foods, such as cereals and canned soups, contain at least one genetically modified organism (GMO). Farmers in the U.S. grow about 10 different types of GM crops, such as corn. The figure below shows how a GMO is created. 93% of the planted area of cornfields were genetically modified varieties by 2014. However, the battle over whether GMOs are safe has led to a very big food fight.



BACKGROUND

The issue of genetically modified (GM) crops is of national, state and local interest because it impacts all consumers, is economically important, ethically controversial, has potential health implications and, as a result, generates political and legal interest. Genetically modified organisms (GMOs) are of national interest, and have a direct impact in the Midwest in particular because of our importance as an agricultural region, which has recently been emphasized due to the national legal battle over corn production. Corn production has been at the center of a legal battle because organic farmers claim that the genetically modified corn crop has contaminated their organic corn crop, resulting in at least one case of the farmer losing his organic certification. The farmer(s) are suing Monsanto for damages, and the issue has gotten the attention of a whole range of stakeholders, including consumers, consumer teams, GM seed producers, and corn farmers.

The Scenario: Your teacher is a representative of the Animal and Plant Health and Inspection Service (APHIS)—the USDA entity charged with regulating genetically modified plants is seeking public input into the issue of GM corn. As an expert in a field directly impacted by GMOs, you are formally invited to represent your team's views in order to help APHIS make a final ruling on this issue. We will participate in a role-playing exercise as our discussion. Each team will be assigned a role to play during this exercise.

Name_______________________________ Date___________ Period _____

1.f. GMO Debate Activity (2/2)

THE DEBATE

Each team is assigned a role and perspective to consider the above options. You will be asked to address the advantages and disadvantages of each option (1-3 above) **from the viewpoint of your assigned stakeholder**. The roles are:

Team 1: *Center for Food Safety (CFS).* The CFS is a non-governmental organization that opposes genetically modified crops in all forms.

Team 2: *The plant biotechnology industry*. You should assume that this industry created the GM technology, is marketing the seeds to farmers, and is processing the corn.

Team 3: *Farmers growing GM corn.* You have been assigned the role of representing farmers growing GM corn.

Team 4: *Organic farmers*. You have been assigned the role of organic farmers. GM corn pollen can blow many miles. You are concerned because your organic customers do not want to purchase corn contaminated with the genes from GM corn.

Team 5: *The scientific community*. You have been assigned the role of researchers conducting research studies on GM crops. You study influences of GM foods on animals and humans.

Team 6: *Consumers*. You have been assigned the role of consumers.

In the debate you will:

1. Introduce yourself to the class as your character. This should include your job, title, education, background and career experience, but can even expand to family history, etc. Enjoy yourself; you take on this role to learn about how stakeholders with this perspective would participate in the discussion, what questions would be important to them, and how diverse ideas can be shared and common understanding created.
2. Which option would your assigned role advocate?
   a. Issue a partial deregulation for the interim to allow planting in certain geographic areas and/or under certain conditions.
   b. Widely deregulate the GMO corn, allowing it to be grown anywhere at anytime.
   c. Refuse to deregulate the GMO corn. Allow for farmers to harvest existing corn, but not to plant anymore.
3. Support your option in terms of scientific, economic, and cultural justifications.
4. What are the potential adverse effects of the proposed options?

Possible Debate Questions

- What is your recommendation for the Food & Drug Administration and APHIS? Why?
- What evidence, facts and issues do you base your recommendation on?
- Who benefits most from your recommendation? Why?
- Who is negatively impacted by your recommendation? Why?

LESSON 2

Introduction to DNA Structure and Function

Lesson Objectives
Students will be able to:
- describe the location and function of DNA.
- follow laboratory protocols and procedures to complete an experiment.
- analyze the results of an experiment to draw conclusions.

Time Required
Two 45-minute class periods

Materials
Per classroom:
- sinks
- towels
- DNA extraction solution (dish soap, salt, and water)
- 90% ice cold rubbing alcohol
- Engineering Design Process poster

Per team:
- (1) large transparent balloon
- (1) small color balloon
- 2 - 5 cm segments of dark color yarn
- (1) plastic bowl
- (10) color beads
- (1) strawberry
- (1) Ziploc freezer bag
- (1) transparent cup
- 50 mL graduated cylinder
- (1) 10 x 10 cm square of cheese cloth/coffee filter
- rubber band
- (1) craft stick
- scissors

Per student:
- engineering notebook
- pencil
- Engineering Design Process slider

Standards Addressed
Next Generation Science Standards: MS-LS1-2

Key Terms
DNA, eukaryotic cell, prokaryotic cell, extraction, double helix

Lesson Summary
This lesson serves as an introduction to the structure and function of DNA. The first part of the lesson is an important assessment to identify any prior knowledge and misconceptions that the students have related to DNA. Then the lesson goes into a review of the cell and the location of genetic material in the nucleus with a modeling activity that will be done in teams. It is important that students understand where the DNA is in the cell and that every cell of all living things has DNA. The DNA extraction lab is to help build students' understanding of the genetics needed for the engineering challenge by showing that they can actually get DNA out of cells from plants/food. Using strawberries, everyday materials, and a simple procedure, students see the DNA from the cells of something that they eat. The lesson ends with students using their T-chart started in the engineering challenge introduction to add questions or knowledge or rearrange the sticky notes.

Background
Teacher Background
In the lesson, students are going to be introduced to DNA and its location in the cell. Students should understand that every cell contains DNA, as well as the basic structure and function of DNA as genetic information for an organism. Students should also understand the differences between prokaryotic and eukaryotic cells, where prokaryotic cells contain no membrane-bound organelles (e.g. bacteria) and eukaryotic cells contain membrane bound organelles, such as a nucleus (e.g. plant and animal cells). Students should also understand the differences between prokaryotic and eukaryotic cells, where prokaryotic cells contain no membrane-bound organelles (e.g. bacteria) and eukaryotic cells contain membrane bound organelles, such as a nucleus (e.g. plant and animal cells).

The lesson begins to connect DNA to the concept of genes and heredity. Students need to have a good understanding of DNA in order to complete the engineering design challenge about genetically modified organisms (GMOs). Students often have exposure to the term DNA and they have some knowledge about human DNA, but could have some misconceptions about where it is found and that all organisms have and need DNA. It will be important to identify some misconceptions about DNA during the lesson so that the activities are used to help students understand the location, function and importance of DNA. This lesson will make the abstract concept of DNA more concrete by using models to illustrate the location and structure.

Before the Activity
- Find a color illustrated image of DNA to show students.
- Purchase and set up lab materials for each activity (1 set per team).
- Determine lab teams (if not done already).
- Make the DNA extraction solution. The solution has 2 tsp of dish soap and ¼ tsp of salt per 10 mL of water. Every team will need 10mL of the solution.
- Chill the rubbing alcohol.
- Make copies of the duplication masters (1 per student).

LESSON 2

Introduction to DNA Structure and Function

Classroom Instruction

Introduction

1. **Assess prior knowledge and identify misconceptions.** Image Brainstorm. Show a color illustrated image of DNA. **Ask:** *What do you see in this image? What is it? What is its function? Why is it important?* Students will observe and write down everything they know about that image. It could be just observations or it could be that the students can identify what the image is and describe it as well as they can. Then, have students write 2-3 questions they would ask about this picture. Instruct students to pair-share one thing they saw or knew about the image and the questions they had. Combine the whole class responses in a chart or Google Docs.

2. **(Optional) Read the client memo.** Have students read the *2.a. Client Memo 1* and discuss the task of the lesson as a class.

3. **Tie to the engineering problem. Ask:** *Why do we need to know the structure and function of DNA?* Take student answers. Guide the discussion so that it reviews the engineering problem, criteria, and constraints.

4. **Identify where they are in the engineering design process. (Learn)** Use the Engineering Design Process poster and students' Engineering Design Process sliders to help students identify what they have done so far and what step they are currently on.

Activity

5. **Build a cell model.** Using balloons, yarn, beads and water, students will model a cell and its contents with their team, following the instructions on the *2.b. Building a Model Cell* worksheet. Individually, have students make observations and drawings of their cells (how it looks, feels, etc.) when it is assembled in their notebooks. Also, have students identify any organelles and distinguishing characteristics about the organelles. **Ask:** *What is interesting about the nucleus? Does it have a membrane?* Then, students should share ideas with their team. Provide a whole team instruction on cell parts (review) and chromosome/DNA location. Instruct students to carefully pop the large balloon into a plastic bowl and draw what they see in their engineering notebooks. Then have students carefully pop the small balloon over a sink or bowl and draw what they see in their engineering notebooks. Instruct students to complete the discussion questions in handout.

6. **Complete the DNA extraction lab.** Students will obtain the *2.c. DNA Extraction: Strawberry* lab handout with the procedure. Instruct students to read procedure and complete pre-lab assignment. Distribute the necessary materials to each student team. Instruct students to follow procedure and extract DNA. Have students make observations, drawings or measurements of the DNA in their notebook. Instruct students to complete the conclusion questions on handout. Conclude with whole class discussion about connecting the idea of strawberries being a crop

Assessments

Pre-Activity Assessment
Check students' observations on the image of DNA and the questions they ask about the image to elicit what students know, do not know, would like to know about DNA.

Activity Embedded Assessment
Throughout the *2.b Building a Model Cell* and *2.c. DNA Extraction: Strawberry*, observe students' work and responses to questions at the end of each activity.

Post-Activity Assessment
Review students' observations, notes, and summaries written in their engineering notebooks. Also, Observe students as they move the Post-its on their T-charts to see what they learned in the activities.

DUPLICATION MASTERS

- **(Optional)** 2.a. Client Memo 1
- 2.b. Building a Model Cell
- 2.c. DNA Extraction: Strawberry

that could be genetically modified to the engineering challenge, and this activity as a potential strategy using DNA extraction to test for GMO cross-contamination and the DNA extracted from the strawberry came from multiple cells.

Closure

7. **Revisit the T-Chart.** Have teams revisit their list of questions or required information on their T-charts to make changes or adjustments to their lists. They can add new information that they'd like to receive from the client and/or they can remove any information they now feel that have adequate knowledge of.

8. **Connect the activity to the engineering design challenge. Ask:** *What science have we learned today to help solve this challenge? How can these activities be used in our engineering design challenge? How else could we use models or a DNA extraction lab?*

Introduction to DNA Structure and Function

LESSON 2

LESSON 2

Name__________________________________ Date____________ Period _____

2.a. Client Memo 1

Dear Student Engineers,

Thank you for agreeing to work with us on this engineering challenge. To develop a prototype testing method, we ask that you use scientific reasoning in your design. To better understand the science behind GMOs, you need to understand where the genetic material of this corn comes from.
We hope that these future activities will provide insight into the genetic material of GMO and non-GMO corn. This information might be useful in your design.

Sincerely,

James Randolf

James Randolf
Organic Outreach Coordinator
University of Minnesota, Agricultural Department

LESSON 2

Name__________________________________ Date____________ Period _____

2.a. Client Memo 1

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Sincerely,

James Randolf

James Randolf
Organic Outreach Coordinator
University of Minnesota, Agricultural Department

40 Got GMOs? FT
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LESSON 2

Name________________________________ Date____________ Period ______

2.b. Building a Model Cell

Materials:

In a bowl gather scissors, various beads (5-10), two short strings of yarn, one small balloon and one large balloon.

Procedure:

1. Fray and put both pieces of yarn into the small balloon.
2. Put the beads into the large balloon.
3. Fill the small balloon with water (not too full) and tie.
4. Put the small balloon in the large balloon.
5. Fill the large balloon with water and tie.

In your notebook:

1. Make observations and drawings of their cells (how it looks, feels, etc).
2. Identify any organelles on the model and in the drawing, and then carefully pop the outer balloon with scissors and write what you see.
3. Pop the inner balloon with scissors and write what you see.

Questions:

1. Where is the DNA located in the cell?

2. What did you all have to do to see the genetic material in the cell?

3. Is the cell prokaryotic or eukaryotic? Explain. (Hint: Compare the location of DNA.)

4. Is this an animal or a plant cell and why?

5. What would be different if we wanted to get DNA from a plant cell?

LESSON 2

Name______________________________ Date__________ Period _____

2.c. DNA Extraction: Strawberry (1/2)

Background: The long, thick fibers of DNA store the information for the functioning of the chemistry of life. DNA is present in every cell of plants and animals. The DNA found in strawberry cells can be extracted using common, everyday materials. We will use an extraction buffer containing salt, to break up protein chains that bind around the nucleic acids, and dish soap to dissolve the lipid (fat) part of the strawberry cell wall and nuclear membrane. This extraction buffer will help provide us access to the DNA inside the cells.

Pre-lab questions:

1. What does extraction mean?

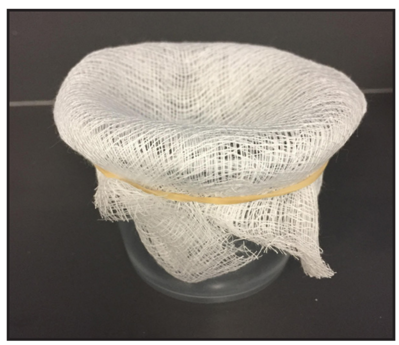
2. Where is DNA found?

3. What do you think the DNA will look like?

Materials:

- Ziploc bag
- 1 strawberry
- 50 mL graduated cylinder
- 10 mL DNA extraction buffer
- cheesecloth/coffee filter
- rubber band
- 1 transparent cup
- 20 mL 90% ice cold rubbing alcohol
- craft stick

Filtration apparatus:



Procedure:

1. Place one strawberry in a Ziploc bag.
2. Smash/grind up the strawberry using your fist and fingers for 2 minutes. Be careful not to break the bag!
3. Add the provided 10mL of extraction buffer to the bag.
4. Smash and mix the strawberry in the bag again for 1 minute.
5. Assemble your filtration apparatus by securing the cheese cloth/coffee to the transparent cup with a rubber band (pictured above).
6. Pour the strawberry slurry into the filtration apparatus and let it drip directly into the cup.
7. Remove the filter and set aside.
8. Slowly pour cold rubbing alcohol into the cup. Do not mix. OBSERVE.
9. Dip the craft stick into the tube where the strawberry extract and ethanol layers come into contact with each other. Slowly pull the stick out of the solution. OBSERVE.
10. Clean up: wash beaker and graduated cylinder. Throw away the bag, cloth and stick. Wipe table and wash hands.

Name_________________________________ Date___________ Period _____

2.c. DNA Extraction: Strawberry (2/2)

Conclusions and Analysis:

1. It is important that you understand the steps in the extraction procedure and why each step was necessary. Each step in the procedure aided in isolating the DNA from other cellular materials. Match the procedure with its function:

Procedure	Function
A. Filter strawberry slurry through cheesecloth	____ To precipitate DNA from solution
B. Mush strawberry with salty/soapy solution	___ Separate components of the cell
C. Initial smashing and grinding of strawberry	___ Break open the cells
D. Addition of ethanol to filtered extract	___ Break up proteins and dissolve cell membranes

2. What did the DNA look like?

3. A person cannot see a single cotton thread 100 feet away, but if you wound thousands of threads together into a rope, it would be visible from much further away. How is this similar to what we did with our DNA extraction? Explain.

4. Why is it important for scientists to be able to remove DNA from an organism? List two reasons.

5. Is there DNA in your food? ________ How do you know?

LESSON 3

Genes and Trait Expressions

Lesson Objectives

Students will be able to:

- define gene, trait, genotype, phenotype, and allele.
- describe the location of DNA and genes in an organism.
- identify or label the structural components of DNA.
- explain how genes are related to traits.
- differentiate a trait as either inherited or environmentally influenced or both.
- explain the structure and function of genes.

Time Required

Two 45-minute class periods

Materials

Per classroom:

- (2) pieces of variegated yarn
- (4) colored page flags
- Engineering Design Process poster

Per team:

- scissors
- glue

Per student:

- (1) PTC tasting strip
- engineering notebook
- pencil
- Engineering Design Process slider

Standards Addressed

- Next Generation Science Standards: MS-LS3-2
- Common Core State Standards - Mathematics: 7.SP.A.1, 7.SP.A.5

Key Terms

gene, trait, genotype, phenotype, allele, DNA, chromosome, double helix

Lesson Summary

This lesson builds on the previous lesson by connecting the structure and function of DNA to genes and trait expressions. Students experience a demonstration in which the expressed genetic trait of their tasting ability is explored. Students taste PTC strips and determine if they are "tasters" or "non-tasters." Then there is a class discussion about genes, alleles, and traits. Variegated yarn and beads are used as a visual aide for students to see and visualize genes on DNA. An exploration of heritable traits follows, in which students compare their own traits to those of their parents and their peers.

Background

Teacher Background

To begin this lesson, students are going to be introduced to a quick demo to determine if they have a gene that allows them to taste PTC paper. This quick demo should quickly introduce the students to the ideas of genes, traits, and genetic differences in individuals. A good tool to help guide the transition from understanding how DNA relates to a gene and to a trait being expressed is to have the students visually see it. The tool that will be used to show this correlation is with the use of variegated yarn. We use variegated yarn because there are different color segments on the yarn that can represent different genes found on a chromosome. The teacher would then use two variegated lines to show that an individual has two chromosomes that were inherited from each parent. Now the teacher can take a bead to represent an allele and place one on each variegated line on a specific gene (color). Students usually have a good understanding that they look like their parents, but probably haven't looked at specific traits to see the correlation. The final activity is designed for students to see their traits, their parents' traits, and hopefully begin to see that traits are inherited from parent to offspring. It is important to understand that the traits described here represent traits that do not follow Mendelian genetics. This means that there are multiple genes that influence these traits. Therefore, it is possible that a student might have a dominant trait while their parents possess the recessive trait.

Key terms that your students should learn in this lesson:

- **Gene -** a unit of heredity that codes for a trait and is passed from parent to offspring.
- **Trait -** a characteristic that may be determined by genetics or the environment
- **Genotype -** an organism's genetic makeup
- **Phenotype -** an organism's physical traits that are determined by its genes
- **Allele -** an alternative form of a gene
- **DNA -** the molecule that carries an organism's genetic information
- **Chromosome -** a structure of DNA and proteins that contain genetic information
- **Double helix -** the helical structure formed by the double strands of DNA
- **Nucleotide -** The chemical bases that make up DNA. These bases have specific pairs that they bind with. A –T and G-C.
- **Chromatin -** when DNA is tightly packaged around proteins to be in a more condensed state for DNA replication

Genes and Trait Expressions

LESSON 3

Phenylthiocarbamide (PTC), also known as phenylthiourea (PTU), is an organosulfur thiourea containing a phenyl ring. It has the unusual property that it either tastes very bitter or is virtually tasteless, depending on the genetic makeup of the taster.

Before the Activity

- Purchase PTC tasting strip (1 per student) and variegated yarn (2 pieces for the classroom).
- Make copies of the duplication master (1 per student).
- Open the link to a video clip on identical twins. Available at: https://www.youtube.com/watch?v=bRKbZtpBcgI or https://www.youtube.com/watch?v=k50yMwEOWGU.
- **(Optional)** Create a PowerPoint with pictures of the genetic traits from the *3.a. Genetic Trait Activity* if you think students are not familiar with these traits.

Classroom Instruction

Introduction

1. **Assess prior knowledge.** Start the lesson by assessing students' prior knowledge about some of the traits or characteristics we see in individuals. **Ask:** *What physical similarities and differences do you see in your teams? What about others in the class?* Students will be given a few minutes to write down as many characteristics ad they know in their engineering notebook. Walk around the room and visually observe students prior knowledge by reading some of their responses. Let the students know that they will be referring to their list a little later in the lesson.

2. **Tie to the engineering problem. Ask:** *Why do we need to know about genes, traits and how they are inherited?* Take student answers. Guide the discussion so that it reviews the engineering problem, criteria, and constraints.

3. **Identify where they are in the engineering design process. (Learn)** Use the Engineering Design Process poster and students' Engineering Design Process sliders to help students identify what they have done so far and what step they are currently on.

Activity

4. **Complete a PTC taste test.** Hand out 1 PTC tasting strip to each student and instruct them to place it on their tongue. Have each student record their taste observation and any explanation to this observation in their engineering notebook. Then have students discard their PTC tasting strip in the trash. As a class, have each student report whether they could or couldn't taste the PTC tasting strip and document this data in a table on the board. The data will be evaluated as a class to see if it correlates to the PTC trait. Have a class discussion about why everyone in the class wasn't able to taste the PTC tasting strip.

Assessments

Pre-Activity Assessment
Check students' responses to the quick write about traits/characteristics that they know of that differentiates each individual. This will help to see if there is any prior knowledge about how traits differ in every individual, such as through siblings, parents and twins.

Activity Embedded Assessment
Listen to students' responses in the classroom discussion about why some individuals could taste the PTC tasting strip and others couldn't. Observe student pairs/teams as they try to identify the traits on the *3.a. Genetic Trait Activity.*

Post-Activity Assessment
Check students' responses to how their traits relate to their parents' traits. Observe students as they move information on their T-Chart to see what they have learn in this lesson.

DUPLICATION MASTERS

- 3.a. Genetic Trait Activity

5. **Complete the allele on variegated yarn demo.** As a demo, take a small portion of variegated yarn (approximately 1 foot) and hold it up to the class. Explain to the class that this is DNA and define the term. Describe how the different colors along the yarn represent different genes that give us different traits, such as whether you can taste PTC or not. The different forms of these genes are termed alleles. Describe how there are two strands of DNA and unravel the piece of yarn to show two identical strands. Place two different colored page markers on the same location on both strands. Explain how these page markers represent the nucleotides that make up DNA and these nucleotides have specific binding pairs. Place two more page markers (of different colors) on the yarn and explain how the A-T and the G-C in DNA and how the sequence of these nucleotides codes for the genes and traits. Wrap the DNA around your hand and describe how DNA becomes condensed when cells undergo replication and this form of DNA is called chromatin. You can then set up two variegated lines with several page markers placed on different genes across the room to serve as a demo for students throughout the rest of the unit. Have students walk around the variegated lines to see them up close and then have students draw these chromosomes with genes in their engineering notebook with labels. Have students draw the results of this in their engineering notebook and then do a quick write about what is being represented with this activity. Also, instruct students to write the definitions of gene, allele, nucleotide, chromatin and trait.

6. **Identify individual traits.** Have students get together with their project teams. In their team, have students take a few minutes to create a list of common traits/characteristics that they have to differentiate one another. Students should refer to the list they created in the opening question to help create a team list. Have each team provide one distinguishing characteristic/trait with the class and record this information on the board. Also, introduce the terms genotype and phenotype and instruct students to write these definitions in their engineering notebooks. Then, handout the *3.a. Genetic Trait Activity* and instruct students to paste it into their notebooks. Go over the list of common genetic traits that are easy to identify in individuals provided on the *3.a Genetic Trait Activity*, using the PowerPoint if needed. In their team, students will help each other to determine whether or not that they have the trait on the list and record this information in the table.

7. **Discuss inherited versus acquired traits.** Show the video clip on identical twins (available at: https://www.youtube.com/watch?v=bRKbZtpBcgI or https://www.youtube.com/watch?v=k50yMwEOWGU). Have students reflect on the video clip. **Ask:** *What major differences are there between inherited and acquired traits?* Determine an area of the classroom to be labeled as "inherited traits" and another as "acquired/environmental traits." Read off a list of traits one at a time, and after each trait have the students move to the side of the room that they think represents the correct nature of the traits. (Example of acquired traits: tanning your skin, freckles, dying hair, tattoos, piercings, colored contacts.)

Closure

8. **Relate students' traits to parents' traits.** Have the students write about some of their traits and how it relates to their parents in their notebooks.

9. **Revisit the T-Chart.** Have the students revisit their list of questions or required information they composed for their engineering design challenge. The students should work with their small teams to make changes or adjustments to their lists. They can add new information that they'd like to receive from the client. **Say:** *As you know from the previous lessons, you will be working to produce a solution for a client, so you'll need to communicate back and forth with the client as questions and ideas come up. We have one letter from the client and have identified some questions you might have, but there is probably a lot more information you would like to have before starting the challenge. This is your opportunity to think of more questions you'd like the client to answer. I'll be sharing our questions with the client later today and will let you know when I hear back.* They can remove any information that they now feel that have adequate knowledge of.

10. **Remind students of the engineering design challenge. Ask:** *What science have we learned today that will help us solve our challenge?*

Name______________________________ Date___________ Period _____

3.a. Genetic Traits Activity

Trait	Description (bold = dominant)	You	Partner 1	Partner 2	Partner 3
Handedness	left or **right**				
Sight	nearsighted or **normal**				
Eye Color	blue or **not blue**				
Dimples	**yes** or no				
Freckles	**present** or absent				
Hair Whorl	**clockwise** or counterclockwise				
Earlobe	**free** or attached				
Tongue	**roller** or non-roller				
White Forelock	**present** or absent				
Widow’s Peak	**present** or absent				
Hitchhiker’s Thumb	yes or **no**				
Bent Little Finger	**yes** or no				
Chin Cleft	**yes** or no				
Mid-digit Hair	**yes** or no				
Toe Length	**2nd toe longer** or 2nd toe not longer				
Hand Clasping	**left thumb on top** or right thumb on top				
Natural Hair Color	**dark** or light				
Natural Hair Type	**curly** or straight				
Nose	**high convex** or straight convex				
Index Finger Length	**long** or short				

LESSON 4 Introduction to Heredity

Lesson Objectives
Students will be able to:
- explain how genes and traits are inherited.
- compare and contrast sexual and asexual reproduction.
- identify organisms that reproduce sexually or asexually.
- examine and identify reproductive organs of a flower/plant.
- explain how fertilization through pollination occurs.

Time Required
Two 45-minute class periods

Materials
Per classroom:
- corn pollination readings
- Engineering Design Process poster

Per team:
- (1) flower

Per student:
- iPad or electronic devices
- engineering notebook
- pencil
- Engineering Design Process slider

Standards Addressed
- Next Generation Science Standards: MS-LS3-2
- Common Core State Standards - Mathematic: 7.SP.A.1

Key Terms
asexual reproduction, sexual reproduction, pollination, sperm, egg, fertilization

Lesson Summary
This lesson serves as an introduction to heredity by focusing on reproduction and how living things inherit genetic material. The lesson uses stations to help students explore and learn about inheritance, asexual and sexual reproduction, as well as plant fertilization through pollination.

Background
Teacher Background
This lesson will be the first formal introduction for the students to the concept of inheritance through reproduction. This lesson builds upon the learning that has taken place in the previous lessons for this unit. At this point, students should have an understanding of how DNA and genes relate to the way an organism looks or other traits that are genetic. There are two modes of reproduction in the natural world: sexual and asexual reproduction. In asexual reproduction, an organism passes on a copy of its entire DNA to its offspring. The offspring is identical to the parent (for the purposes of middle school life science) because it received an identical copy of the parent's DNA. Since DNA contains the genotype that results in the phenotype, the DNA for the offspring will produce identical physical characteristics as the parent. In sexual reproduction, half of the DNA an offspring receives comes from its mom, and half comes from its dad. This method of reproduction yields offspring that look different than either individual parent because the DNA has been combined in a new way. This method also allows for (essentially) unlimited combinations of the DNA since each parent only passes on one allele for each gene, which is then combined with one allele for each gene from the other parent. The number of permutations possible for the combination of genes is very large, which means each offspring from a given set of parents can and will be genotypically and phenotypically unique. This lesson will also let students explore how plants reproduce sexually through pollination. Self-pollination and cross-pollination can fertilize a plant and lead to new offspring in the form of a seed. Students should have a good visual understanding of how pollination occurs in plants. Students should also learn the pollination process of corn and that corn usually cross-pollinates through the wind.

Before the Activity
- Make copies of the *4.a. Reproduction Stations* handouts (2 of each station for the classroom). Label the station areas in the classroom. NOTE: You only need one introduction page per station.
- Purchase flowers and keep in water (1 per team). If kept overnight, place in refrigerator. Before class, you might want to cut flower in half to help students identify structures.
- Make copies of the corn pollination handouts for students without electronic devices. The links are shown on Station 4: Corn Reproduction and Pollination.

Classroom Instruction
Introduction
1. **Complete a quick write.** Have the students answer these questions in their notebooks: *Why do we look the way we do? How do plants pass on their DNA?*

2. **Tie to the engineering problem. Say/Ask:** *We have spent several lesson learning about the science of genetics. What is the purpose of this? What else do we have left to learn?* Take student answers. Guide the discussion so that it reviews the engineering problem, criteria, and constraints.

3. **Identify where they are in the engineering design process. (Learn)** Use the Engineering Design Process poster and students' Engineering Design Process sliders to help students identify what they have done so far and what step they are currently on.

Activity

4. **Complete the *4.a. Reproduction Stations*.** Have students rotate through the stations labeled in the classroom. There should be two teams at each station. NOTE: If you need to have more than 8 teams, you may need to make extra copies of the station handouts.
   - **Station 1: Inheritance.** Students will complete a reading and look at images. Have a team discussion about how genes get inherited and write a summary in their engineering notebooks.
   - **Station 2: Asexual vs. Sexual Reproduction.** Students will complete a reading about what each is and the benefits and costs of each form of reproduction. Have students create a Venn diagram comparing/ contrasting sexual and asexual reproduction in their notebook.
   - **Station 3: Plant Reproduction.** Students will read how plants are fertilized by pollination. Then have students examine a real flower and identify sexual organs on the flower using a diagram you provide. Students will draw their flower and label the parts in their notebook. If there is time, have them look at the plant's life cycle diagram for review. NOTE: For this station, there is a page with an unlabeled flower. You may print out copies of this for each student to paste in their notebook for labeling (to avoid drawing the flower).
   - **Station 4: Corn Reproduction and Pollination.** Students will have independent research time to help identify information that they need to know about the life cycle of corn and the methods by which it pollinates. Students should take notes on the information that they find. They may use their electronic devices (iPads or computers) or you may leave paper resources for students. NOTE: For this station, you may print out the introduction page so students do not have to rewrite the questions in their notebooks.

   Summarize all the stations with a final class discussion.

Closure

5. **Revisit the T-Chart.** Have the students revisit their list of questions or required information they composed for the engineering design challenge. The students should work with their small teams to make changes or adjustments to their lists. They can add new information that they'd like to receive from the client and/or remove any information they now feel that have adequate knowledge of.

Assessments

Pre-Activity Assessment
Check students' responses to the quick write at the beginning of the lesson to determine if the students have a solid understanding of how traits are controlled by genes.

Activity Embedded Assessment
Observe students' during the *4.a. Reproduction Stations* and check students' summaries and notes in their notebooks to determine if the student are completing work and gaining understanding toward the learning goals. Review students' Venn diagrams created in Station 2: Asexual vs. Sexual Reproduction to see if students understand the differences and similarities between asexual and sexual reproduction.

Post-Activity Assessment
Observe students as they move information on their T-Chart to see what they have learn in this lesson.

DUPLICATION MASTERS

- 4.a. Reproduction Stations

Introduction to Heredity

6. **Complete an individual summary.** Have the students complete an exit ticket, summarizing the four main ideas from the lesson.

7. **Connect these activities to the engineering design challenge. Ask:** *What science did we learn to help us solve the engineering design challenge? How does inheritance relate to GMOs? How do plants pass genes on to offspring?*

Introduction to Heredity

Station 1: Inheritance

Learning Goal: Explain how the traits of an organism are inherited.

Instructions:

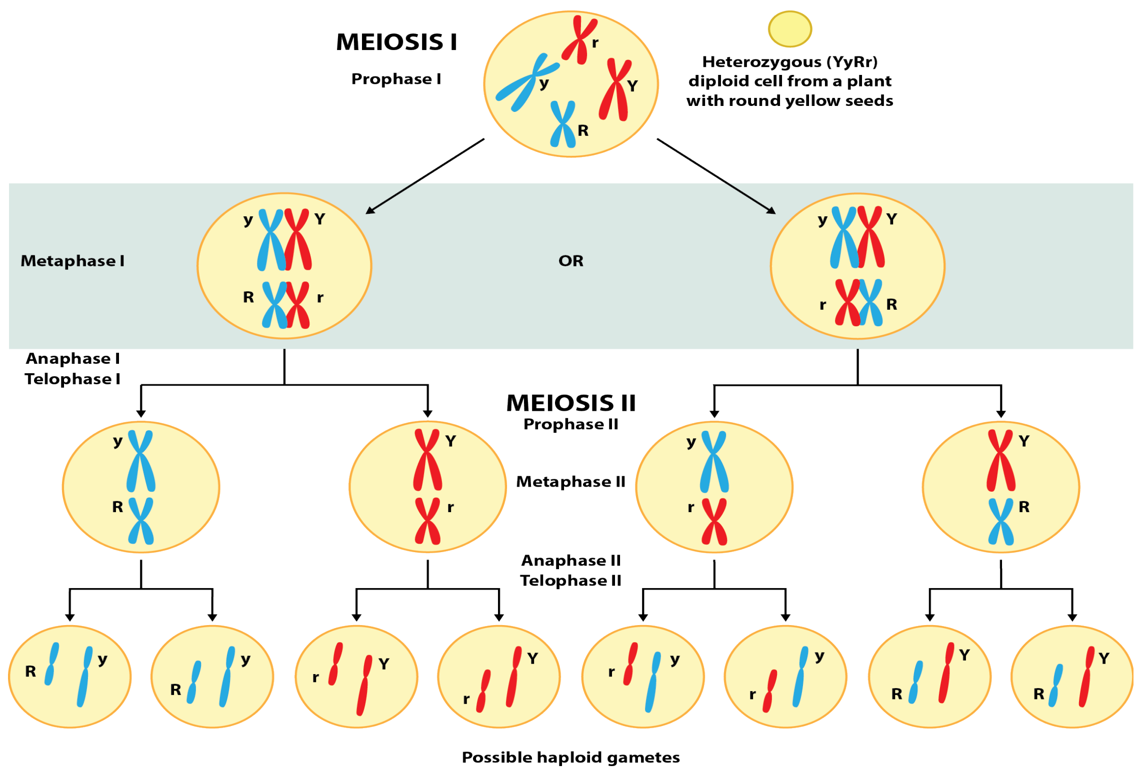
1. Complete the reading and look at the figures.
2. Have a team discussion using the following sentence starters:
   - I found it interesting…
   - I read that…
   - I agree with the reading about…
   - I learned that….
   - I am still wondering about…
3. Write a 3-5 sentence summary in your notebook.

LESSON 4

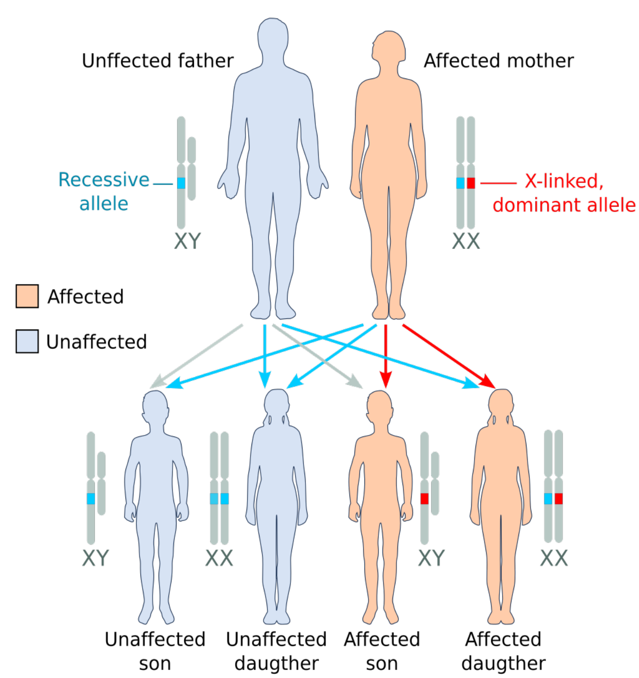
4.a. Reproduction Stations

Station 1: Inheritance

Sexually reproducing organisms, such as plants and animals, make their sex cells or **gametes** with only half of their chromosomes and genes in each cell. One parent gives half of the genes and one allele for each trait and the other parent gives the other half of the genes and one allele for each trait. This process is termed **meiosis**, as shown to the right. The parent cell has 4 chromosomes and then undergoes two rounds of cell division to produce four daughter cells that contain 2 chromosomes. When the cell has half the number of chromosomes as the parent cell, it is called a **haploid cell.** The parent cell with the full number of chromosomes is called a **diploid cell.**



The parents have diploid cells, and their gametes are haploid. After **fertilization**, the offspring ends up with a complete set of genes and two alleles for each trait. It is the alleles that determine the trait the offspring will show. Some alleles are hidden; these are called recessive alleles that are overpowered by dominant alleles, so you cannot always determine which alleles the offspring has even if you can see a trait. Example: Blue eye allele is hidden by the brown eye allele, so people with brown eyes may still have a blue eye allele.



The half of the parental genes that the offspring will inherit is random, so the study of inheritance uses probability to predict the alleles and traits of an organism. The illustration to the right shows the genes combinations that could be inherited. The probability that the offspring in this figure will inherit the affected trait, shown in orange, ½ or 50%.

Station 2: Sexual vs. Asexual Reproduction

Learning Goal: Compare and contrast sexual vs. asexual reproduction.

Instructions:

1. Complete the reading about sexual vs. asexual reproduction.

2. Make a Venn diagram comparing and contrasting both ways of reproduction in your engineering notebook.

Station 2: Sexual vs. Asexual Reproduction

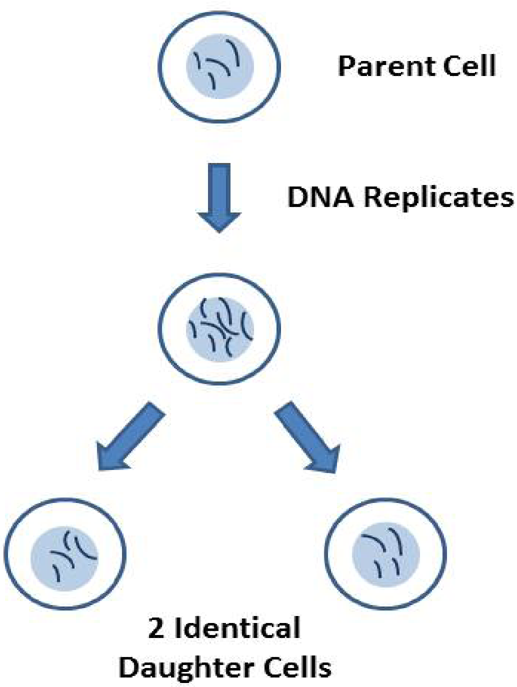
Reproduction

In order for plants and animals to survive, these organisms must reproduce. Reproduction is the ability to produce offspring and future generations. Organisms can reproduce in two ways, asexual and sexual reproduction. They both have advantages and disadvantages, but they both result in a new organism.

1. **Asexual reproduction:** Process where a new individual is formed from a single parent.
2. **Sexual reproduction:** Process where a new individual is formed from two parents.

Asexual Reproduction

For humans, two parents are necessary for reproduction. Genetic information in the form of DNA is combined from the mother and father and then passed onto the child. For humans, two parents are necessary, so they are considered to reproduce sexually. Other organisms, however, are able to reproduce asexually, meaning that **they can reproduce with only one parent**. Not only do these organisms reproduce from a single parent, but they also share the **same genetic information as their parent**. Examples of this are seen in some plants, insects, fish, reptiles and bacteria.



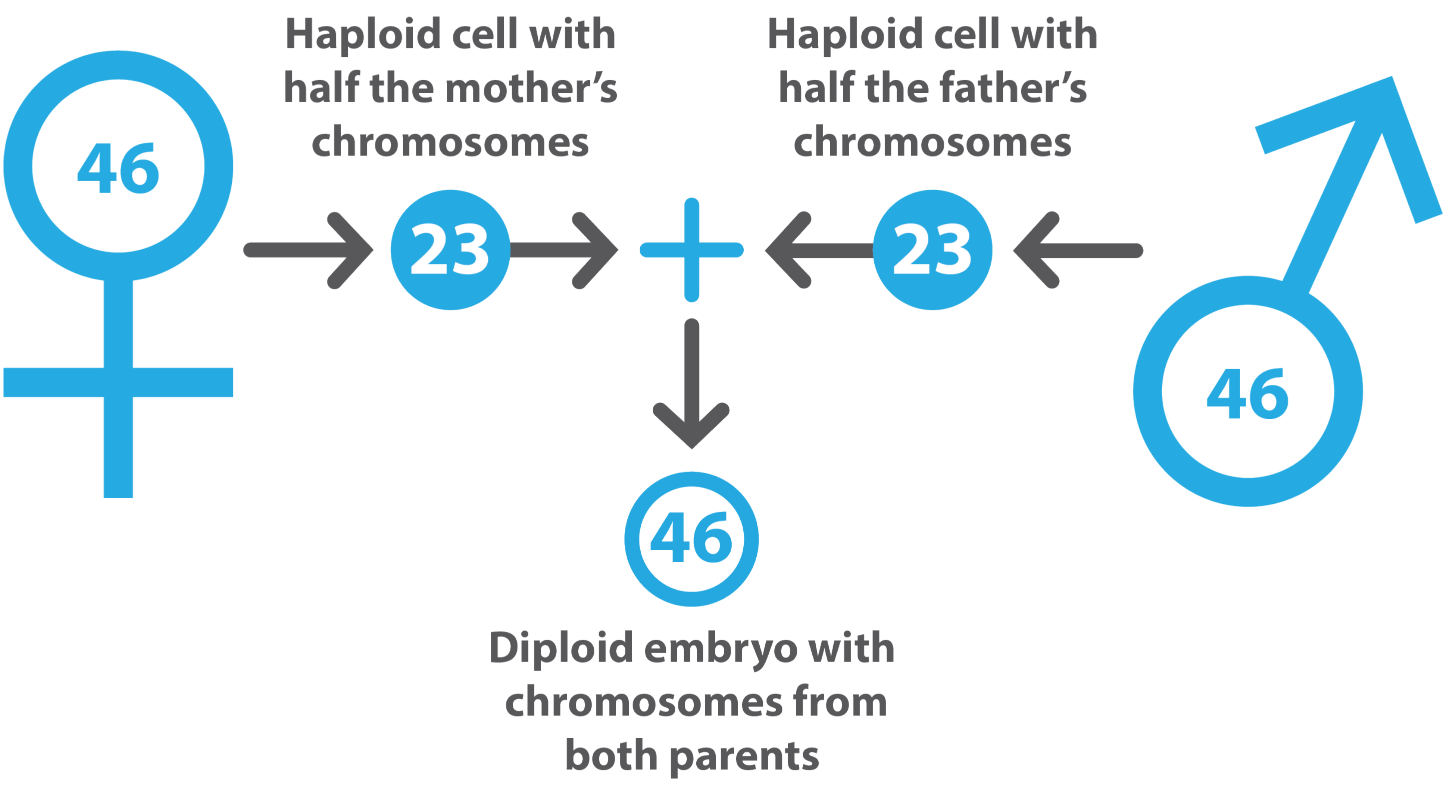
One advantage of asexual reproduction is that it is a very quick process and does not require a male and female organism to meet. Unfortunately, the lack of a male and female means that the organism does not receive a mix of traits from both parents which serves as a disadvantage. This organism only has DNA from one parent and is an exact copy of the parent. This is a disadvantage for the organism if the parent has a gene for a disease or undesirable trait. Since this organism undergoes asexual reproduction, there is a 100% chance that the organism will inherit that trait. That would not be the case in sexual reproduction because that organism would receive a mixture of genes from both parents, meaning that the chance of inheriting the undesirable trait is less probable.

4.a. Reproduction Stations (2/2)

Sexual Reproduction

In contrast to asexual reproduction, sexual reproduction requires two parents. In these organisms, such as humans, you can have females that produce **eggs** and males that produce **sperm**. During fertilization, the sperm and egg meet and form a zygote. A **zygote** is the first cell of an organism that has genetic information from both parents. This organism will then undergo many rounds of **mitosis** and develop into an embryo. Since the genetic information is randomly mixed from the mother's and father's cells, the resulting **zygote is genetically unique**.

Sperm and egg cells are called **gametes,** and these contain half of the DNA from each parent. These gametes result from a process called **meiosis**. Therefore, when the two gametes combine, the resulting zygote has the correct number of DNA. For example, humans have 46 chromosomes. Therefore, each sperm and egg cell has 23 chromosomes. When the sperm and egg meet, the 23 chromosomes from the mother will combine with the 23 chromosomes from the father and the embryo now has 46 total chromosomes.



Station 3: Plant Reproduction

Learning Goal: Examine and identify the reproductive organs of a plant.

Instructions:

1. Read the short reading together.
2. Identify the parts on the flower.
3. Make a drawing in your engineering notebook.

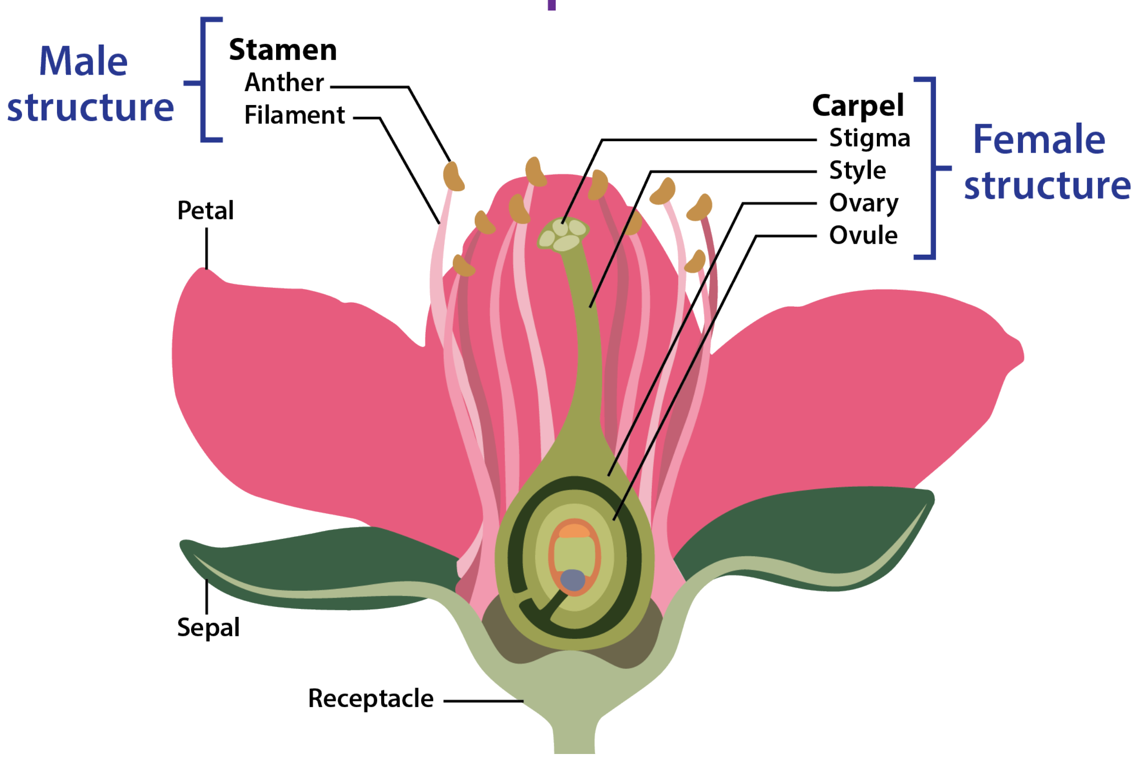
4.a. Reproduction Stations

Station 3: Plant Reproduction

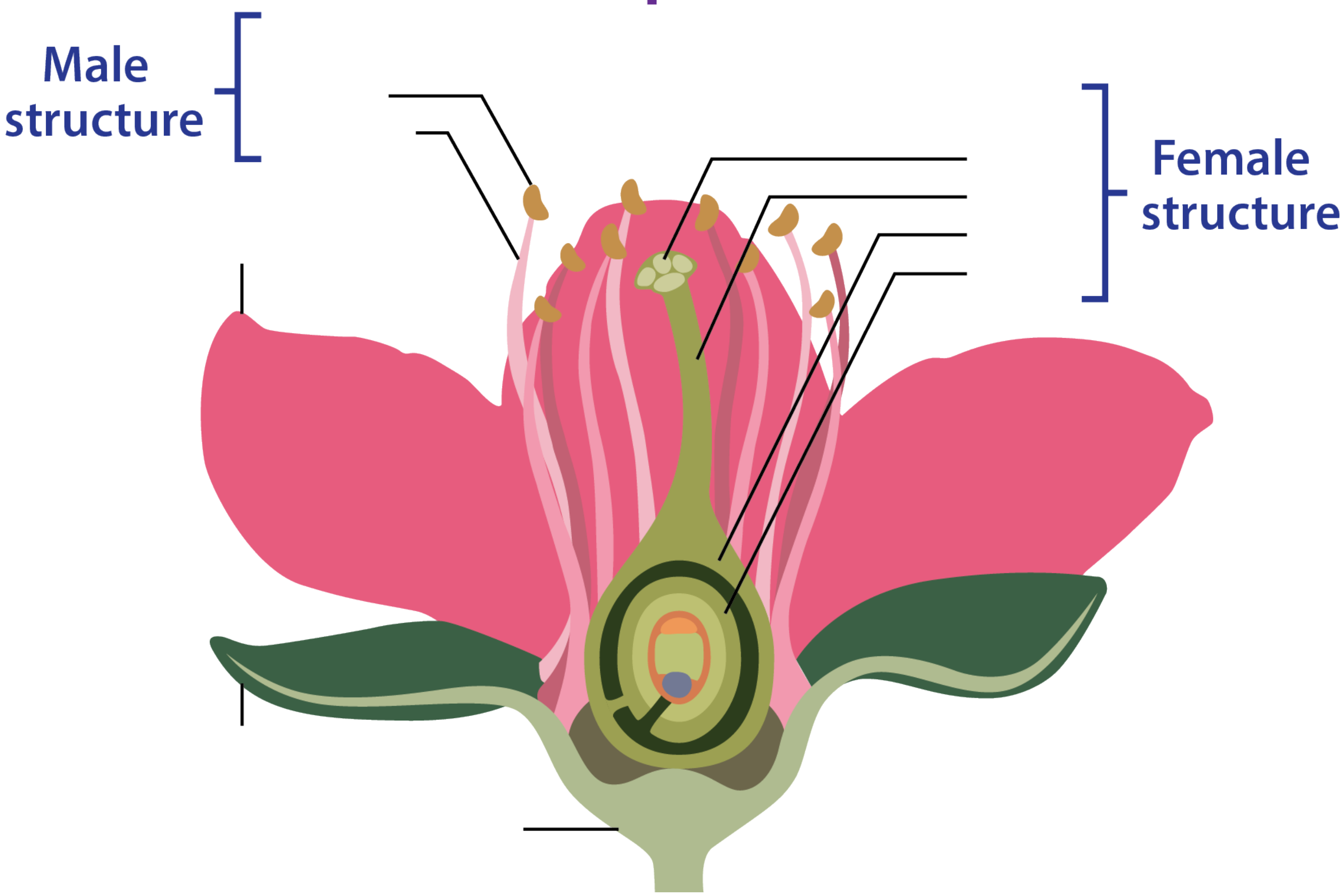
Plants, such as corn, have reproductive organs in their flowers. The sperm is contained within the **pollen**, while the egg is contained within the **ovary**. For the sperm to reach the egg and create a fertilized embryo, a plant must undergo one of the following processes:

1. **Self-pollination:** The egg is fertilized by the pollen from the same flower. This is a quick and easy process.
2. **Cross-pollination:** The sperm from one flower fertilizes the egg of another flower that is the same species. This is similar to sexual fertilization because you see a variety of traits formed by the combination of the two parents. Cross-pollination occurs when **wind** carries pollen from another flower. Alternatively, insects, such as bees and butterflies, can serve as **animal pollinators**. These animal pollinators carry pollen and are able to distribute the pollen from flower to flower.

Parts of an insect pollinated flower



Parts of an insect pollinated flower



Station 4: Corn Reproduction and Pollination

Learning Goal: Research topics related to the crop of corn and the method of pollination.

Instructions:

1. Use your electronic device to search for answers about corn pollination.
2. Write any information that you find in your notebook.

Some of our questions included:

- How does a corn plant pollinate?
- What is cross-contamination of pollen?
- What does corn pollen look like?
- What time of year does corn pollinate?
- How far can corn pollinate?

4.a. Reproduction Stations

Station 4: Corn Reproduction and Pollination

Some good websites to start with:

- https://www.geneticliteracyproject.org/2013/12/09/how-to-prevent-gm-corn-from-contaminating-cross-pollinating-non-gmo-fields/
- http://blog.seedsavers.org/blog/preventing-gmo-contamination-in-your-open-pollinated-corn
- http://www.agbioforum.org/v4n2/v4n2a02-jemison.htm
- http://homeguides.sfgate.com/can-two-different-types-sweet-corn-cross-pollinate-76581.html
- http://www.aganytime.com/Pages/Article.aspx?name=A-Closer-Look-at-Corn-Pollination&fields=article&article=910

LESSON 5 Applied Heredity

Lesson Objectives

Students will be able to:

- create a Punnett square to represent inheritance of traits.
- analyze a Punnett square to calculate probability and make predictions.
- calculate the probability of a particular trait being passed down to an offspring.
- predict the traits that would be present in an offspring.
- explain inheritance of dominant and recessive alleles.

Time Required

Two 45-minute class periods

Materials

Per classroom:

- Engineering Design Process poster

Per team:

- (6) 1-centimeter square cubes of 1 solid color (red)
- (6) 1-centimeter square cubes of 1 solid color (blue)

Per student:

- engineering notebook
- pencil
- Engineering Design Process slider

Standards Addressed

- Next Generation Science Standards: MS-LS3-2
- Common Core State Standards - Mathematics: 7.SP.A.1, 7.SP.A.5

Key Terms

gene, allele, trait, chromosome, homozygous, heterozygous

Lesson Summary

This lesson serves as an introduction to heredity and probability of inheritance using Punnett squares. Start by reviewing reproduction and DNA inheritance. The main goal of the lesson is to get students to understand how alleles are inherited and how to complete a problem to assign probabilities to the genes and traits the offspring inherits.

Background

Teacher Background

The lesson teaches basic genetic inheritance of dominant and recessive alleles and connects mathematical reasoning to the science with the teaching of probability of inheritance. Students should have a good understanding of heredity of genetic information, probability, and rules of basic inheritance after the lesson is complete. They should also understand that probability of inheritance is a theoretical probability, meaning that the probability they determine may not occur in the natural world. Students can use this knowledge when thinking about the engineering challenge and how a plant reproduces and inherits certain traits. This basic genetic inheritance is important to the understanding of how genes are genetically modified in plants and how GMO genes could then be inherited to offspring plants.

Key terms that your students should learn in this lesson:

- **Homozygous** - Having the identical alleles for a certain gene.
- **Heterozygous** - Having two different alleles for a certain gene.

Before the Activity

- Prepare visual aids for the discussion on heredity.
- If needed for reference, prepare the story of Mendel and Mendelian genetics. Available at: http://peer.tamu.edu/curriculum_modules/Cell_Biology/Module_4/storytime.htm.
- Read the *5.a. 3-D Punnett Square Activity*. Sort the centimeter cubes by colors (1 of each color per student).
- Make copies of duplication masters:
    - *5.a. 3-D Punnett Square Activity* (1 per every two or three students)
    - *5.b. Mendelian Genetics* (1 per student)
    - **(Optional)** *5.c. Alien Genetics* (1 per student)
    - *5.d. Genetics Practice Problems* (1 per student, these are examples and can be changed at your discretion)

Classroom Instruction

Introduction

1. **Discuss heredity.** Review heredity and apply heredity to crops or plants to connect it to their problem. Using multiple scenarios and visual aids, have students make predictions about what offspring plants will look like based on the parents' traits.

2. **Tie to the engineering problem. Say/Ask:** *We have spent several lesson learning about how genes are passed from parent to offspring. What is the purpose of this?* Take student answers. Guide the discussion so that it reviews the engineering problem, criteria, and constraints.

3. **Identify where they are in the engineering design process. (Learn)** Use the Engineering Design Process poster and students' Engineering Design Process sliders to help students identify what they have done so far and what step they are currently on.

Activity

4. **Introduce the lesson.** Tell a story of Mendel and Mendelian genetics. **Ask:** *How can we use Mendelian genetics today? Is this useful for our challenge?* Review dominant and recessive inheritance in terms of what was observed. Introduce genetic crosses in terms of inheritance and sexual reproduction (e.g. Tt x Tt). Define homozygous and heterozygous alleles and have students think-pair-share through some examples using allele pairs and traits of plants. **Ask:** *What traits did Mendel observe in his experiments? What about traits of corn?*

5. **Introduce the Punnett square activity.** If students are in teams of 4, have them pair up. If they are in teams of 3, they may work as a team. Hand out two 1-centimeter cubes to each student pair/team, one of each color (representing heterozygous alleles). Have students pair-share to identify the parents as heterozygous or homozygous. **Ask:** *How can you tell?* Have students pick an allele from each parent to represent a recombination of alleles in gametes. Survey the class to see the different combinations. If there are any missing combinations, ask if there are any other possibilities (there should be 4).

6. **Discuss combinations.** All four of the cube combinations that they chose are the different ways the alleles could combine from the two parents during reproduction. There is a good way to organize the combination to try and predict the alleles of the offspring: the Punnett square.

7. **Introduce Punnett squares.** Ask students to draw a Punnett square in their engineering notebook that is large enough to fit two centimeter cubes. Hand out the *5.a. 3-D Punnett Square Activity* and have students read the first page to reiterate what they have learned. Explain to students that the top and side are the parent alleles and the inside are the offspring combinations. Have them use their heterozygous parents to set up the Punnett square. Hand out more cubes. Model for the students how to organize the cubes for the offspring (bring them down and over) and complete at least one together.

8. **Discuss the results. Ask:** *What will the offspring look like? How many will be dominant and how many recessive? What are their genotypes and phenotypes? Homozygous or heterozygous?* Introduce probabilities and expected outcome of the offspring (i.e. parents that are heterozygous have ¾ dominant and ¼ recessive offspring).

9. **Summarize the activity.** Have students finish the activity in teams of two or three. Students should summarize in writing the rules of dominant and recessive inheritance and define homozygous and heterozygous allele combinations in their engineering notebooks.

Assessments

Pre-Activity Assessment
Check students' predictions to what offspring will look like based on the parental traits.

Activity Embedded Assessment
Listen to students' responses as they pair-share about what they know about heredity and Punnett squares. Also listen to students' discussions about the results as they go through the genetic worksheets. Review the answers to the genetic problems through a whole-class discussion, making sure to discuss the more difficult problems and address any misconceptions the students may have on heredity.

Post-Activity Assessment
Listen to students' responses and justification about how they would change their answers to the pre-assessment. Review students' responses' to the exit ticket based on the *5.d. Genetics Practice Problems* to assess how well students can complete a genetics problem.

DUPLICATION MASTERS

- 5.a. 3-D Punnett Square Activity
- 5.b. Mendelian Genetics
- **(Optional)** 5.c. Alien Genetics
- 5.d. Genetics Practice Problems

10. **Practice genetics problems.** Introduce Punnett square problems using letters for alleles and complete simple crosses using letters to practice. Handout copies of the *5.b. Mendelian Genetics*, which will relate what they learned to Mendelian genetics and also give students practice with more difficult Punnett squares. **(Optional)** If some students complete the worksheet quickly, they may complete *5.c. Alien Genetics.* This worksheet may also be used if you feel the students need more practice.

Closure

11. **Revisit the introduction.** Revisit the introduction pre-assessment and ask the students how they think they would change their predictions. Have students explain why and then pair-share.

12. **Revisit the T-Chart.** Have the students revisit their list of questions or required information they composed for their engineering design challenge. The students should work with their small teams to make changes or adjustments to their lists. They can add new information that they'd like to receive from the client and/or remove any information that they now feel that have adequate knowledge of.

13. **Complete an exit ticket.** Give three genetics problems, of the teacher's choosing, in increasing difficulty, and have students independently complete the problems. Example problems are shown in *5.d. Genetic Practice Problems*. Formally assess the problems by walking around and asking questions and by assessing the final papers that the students turn in at the end.

14. **Connect to engineering design challenge. Ask:** *How can we use inherited traits and Punnett squares in our engineering design challenge?*

Applied Heredity

LESSON 5

Name________________________________ Date____________ Period _____

5.a. 3-D Punnett Square Activity (1/2)

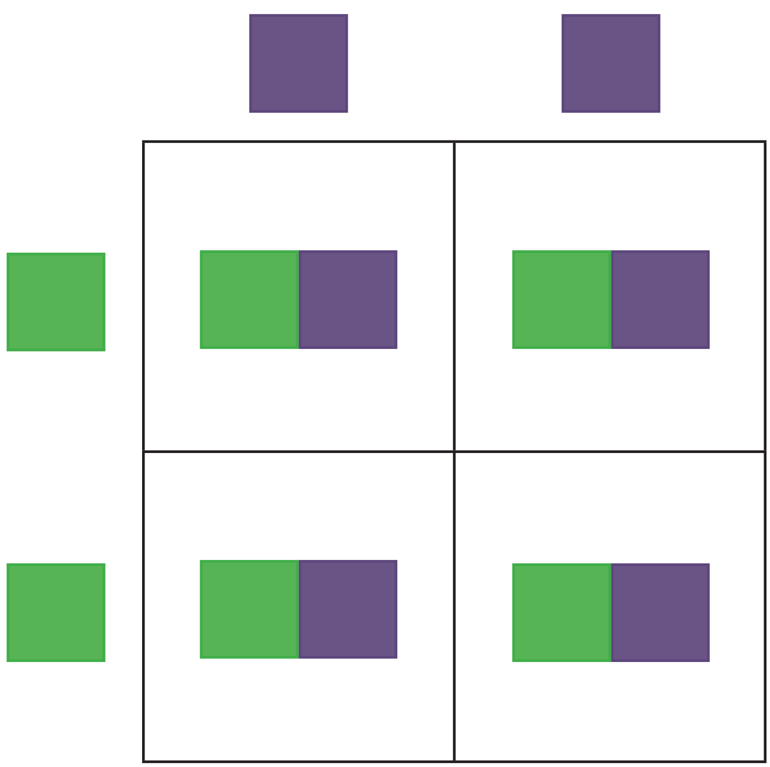
Overview

In biology, we use Punnett Squares to help us understand genetic traits and how offspring may inherit these traits from two parents. Each trait results from at least one gene, but it is important to know that many genes have alternate forms. These alternate forms of a gene are called alleles. For example, corn plants can be tall, which is either homozygous dominant (TT) or heterozygous (Tt), or corn can be short, which is homozygous recessive (tt). These traits are considered to be dominant when one allele masks the other. The hidden allele is considered to be recessive. In this example, T is the dominant allele.

If a pair of alleles from a male corn plant is crossed with a matching pair from a female plant, we can create a Punnett Square to see what traits are expressed in their offspring. This also allows us to calculate the probability of the offspring expressing a specific trait. Some of these traits could even be sex-linked, meaning they are located on sex chromosomes and the sex of the offspring affects whether the organism inherits that trait. When genes are not located on the sex chromosomes, they are called autosomal.

To better understand how to use a Punnett Square, we can use 3-D representations. In the example below, the purple squares represent the homozygous dominant trait where the green squares represent the homozygous recessive trait. The resulting offspring all have a mix of purple and green squares. Therefore the offspring are heterozygous.

Use the colored squares to help you answer questions on the following crosses on corn height, where tall corn (T) is dominant over short corn (t). One cube color will represent the dominant allele (T) and the other cube color will be recessive allele (t).



LESSON 5

Name_______________________________ Date___________ Period _____

5.a. 3-D Punnett Square Activity (2/2)

Dominant allele (T) cube color: ____________________________________

Recessive allele (t) cube color: ____________________________________

1. Cross TT x TT and write the resulting offspring. What is the probability that the offspring will express the dominant trait?

2. Cross TT x Tt and write the resulting offspring. What is the probability that the offspring will express the recessive trait?

3. Cross Tt x Tt and write the resulting offspring. What is the probability that the offspring will express the dominant trait?

4. In the previous cross, is it possible that two corn plants could produce two plants and have them both be homozygous? Why or why not?

5. The two heterozygous corn plants from Question 3 produced the following data over the course of five growing seasons. Is it possible for these results to occur?

Growing Season	# of Tall (TT or Tt) corn	# of short (tt) corn
1	65	35
2	77	23
3	51	49
4	70	30
5	62	38

LESSON 5

Name________________________________ Date___________ Period _____

5.b. Mendelian Genetics (1/2)

Directions: One of the traits of pea plants that Mendel observed was seed shape. Seeds were either round or wrinkled. Mendel observed that the round seed shape (R) dominated over the wrinkled shape (r). Complete the Punnett square to show the possible offspring of two heterozygous pea plants. Then answer the questions that follow.

1. What phenotypes for seed shape did Mendel observe?

2. What was the phenotype for seed shape of both parent plants?

3. What was the genotype for seed shape of both parent plants?

4. What percentage of the possible types of offspring had the same genotype as the parents?

5. What percentage of the possible types of offspring was homozygous?

6. What percentage of the possible types of offspring had the same phenotype as the parent?

Name________________________________ Date___________ Period _____

5.b. Mendelian Genetics (2/2)

7. What is the genotype of the offspring that did not share the parents’ phenotype?

8. What is the probability that two heterozygous parents would have an offspring with round seeds? (Express your answer as a ratio.)

9. Define genetics.

10. What role do genes play?

Name________________________________ Date____________ Period _____

5.c. Alien Genetics (1/3)

Scientists at NASA have been investigating the genetic makeup of a new species of aliens on the planet Neptune. Use the information provided and your knowledge of genetics to answer each question.

1. For each genotype below, indicate whether it is a heterozygous (He) OR homozygous (Ho).

   TT _____ Bb _____ DD _____ Ff _____ tt _____ dd _____
   Dd _____ ff _____ Tt _____ bb _____ BB _____ FF _____

2. Determine the phenotype for each genotype using the information provided about the aliens.

   Yellow hair is dominant to blue hair.

   YY_______________ Yy_______________ yy_______________

   Dark eyes are dominant to white eyes.

   DD_______________ Dd_______________ dd_______________

3. For each phenotype, give the genotypes that are possible for the aliens.

   A tall body (T) is dominant to short.

   Tall = ____________________ Short = ____________________

   A furry body (F) is dominant to a hairless body.

   Furry = ____________________ Hairless = ____________________

4. A male alien named Patrick has recently married a female alien named Susie. Patrick is heterozygous for his tall body, but Susie is short.

   a. List the genotypes and phenotypes of Susie and Patrick.

	Genotypes	Phenotypes
Susie		
Patrick		

Name________________________________ Date____________ Period ______

5.c. Alien Genetics (2/3)

b. Create a Punnett square to show the possibilities that would result if Patrick and Susie had children. What are the chances of a child with a tall body? What are the chances of a child with a short body?

Tall:

Short:

5. Alien Marshall met alien Mandy at a dance. Both of them are heterozygous for their yellow hair color.

a. List the genotypes and phenotypes of Mandy and Marshall.

	Genotypes	Phenotypes
Mandy		
Marshall		

b. Create a Punnett square to show the possibilities that would result if Marshall and Mandy had children. What are the chances of a child with yellow hair? What are the chances of a child with blue hair?

Yellow:

Blue:

Name________________________________ Date____________ Period ______

5.c. Alien Genetics (3/3)

6. Everyone in alien Paul's family has blue skin, which is the dominant trait for body color on his planet. His family brags that they are a "purebred" (homozygous) line. He recently married a nice girl who has green skin, which is a recessive trait. Use B to represent the dominant gene and b to represent the recessive gene.

   a. List the genotypes and phenotypes of Paul and his wife.

	Genotypes	**Phenotypes**
Paul		
Wife		

   b. Create a Punnett square to show the possibilities that would result if Paul and his new bride had children. What are the chances of a child with blue skin? What are the chances of a child with green skin?

Blue:

Green:

   c. Would Paul's children be considered "purebreds"? Explain.

LESSON 5

Name________________________________ Date____________ Period _____

5.d. Genetics Practice Problems

1. Debbie and Ryan are curious what their children's eye colors will be. Debbie has green eyes and Ryan has brown eyes. Green (b) is recessive and brown (B) is dominant. The problem is, Ryan doesn't know if he is homozygous or heterozygous.

   a. Create a Punnett square for Debbie and Ryan, where Ryan is homozygous dominant.

   b. Create a Punnett square for Debbie and Ryan, where Ryan is heterozygous.

   c. After a year, Debbie gives birth to a beautiful baby boy. This boy has brown eyes. Can we determine Ryan's genotype? Why or why not?

   d. A year later, Debbie gives birth to a beautiful baby girl. This baby has green eyes. Can we figure out Ryan's genotype now? Why or why not?

LESSON 6

Genetic Modification

Lesson Objectives

Students will be able to:

- explain what a GMO is and how it is created.
- explain how the properties of DNA can be used to identify GMOs.

Time Required

Two 45-minute class periods

Materials

Per classroom:

- Engineering Design Process poster

Per team:

- scissors
- glue

Per student:

- engineering notebook
- pencil
- Engineering Design Process slider

Standards Addressed

- Next Generation Science Standards: MS-LS3-2
- Common Core State Standards - Mathematics: 6.SP.B.5a, 6.SP.B.5b, 7.SP.A.1, 7.SP.A.5

Key Terms

genetic transformation, plasmid, cloning, enzyme, restriction enzyme

Lesson Summary

This lesson serves as an introduction to basic genetic engineering. Students practice splicing a gene using a paper plasmid. They physically cut the plasmid using scissors to represent how restriction enzymes are used to cut DNA at specific sites. Then, they tape a length of paper DNA into the plasmid to reconnect it to represent how DNA at restriction sites come together. This activity will help students understand how GMOs are created.

Background

Teacher Background

This lesson will be the first encounter that students have with genetically modified organisms (GMOs). This lesson builds upon prior knowledge about traits, genes, and DNA, so it will be crucial that students have a solid foundation before starting this lesson. Genetically modified organisms (GMOs) are organisms that have been created through gene-splicing techniques. This process allows desired genes from one species to be extracted and inserted into another species' DNA, creating combinations of plant, animal, bacteria, and viral genes that do not occur in nature or through traditional crossbreeding methods.

Before the Activity

- Review the *6.a. Gene Splicing Background.*
- Prepare the video on genetically modified animals and gene splicing.
    - Genetically modified animals: https://www.youtube.com/watch?v=TJu8sWZDhU4
    - Gene splicing: https://www.youtube.com/watch?v=AEINuCL-5wc
- Make copies of the duplication master (1 per every two or three students).

Classroom Instruction

Introduction

1. **Show a demonstration of genetically modified animals.** Begin this lesson with a demo to hook the kids to the idea of altering an organism through genetic modification. Start by watching the following video on genetically modified animals (available at: https://www.youtube.com/watch?v=TJu8sWZDhU4). Have the students document anything they observe about the animals in their engineering notebooks. Call on a few students to share their observations and thoughts. Talk about these animals and why the demo was completed to engage the students for the rest of the activities in the lesson. Describe how these animals were genetically modified, similar to the plants in the engineering design challenge.

2. **Tie to the engineering problem. Say/Ask:** *We have spent several lesson learning about the science of genetics. What is the purpose of this?* Take student answers. Guide the discussion so that it reviews the engineering problem, criteria, and constraints.

3. **Identify where they are in the engineering design process. (Learn)** Use the Engineering Design Process poster and students' Engineering Design Process sliders to help students identify what they have done so far and what step they are currently on.

Activity

4. **Complete the gene splicing activity.** Have students pick a partner from their project teams if they are in teams of 4. Have them work in teams of 3 otherwise. Each pair/team will receive a *6.b. Gene Splicing activity worksheet*. As a class go over any key terms that haven't been covered using the *6.a. Gene Splicing Background.* Show the video on gene splicing to demonstrate it to the students (available at: https://www.youtube.com/watch?v=AEINuCL-5wc). This activity serves to help students understand how to make a genetically modified organism. To save on time, you can pre-cut the DNA for the students and tape or glue them into rings. Students will be able to see how genetically modified organisms are made by inserting mutant superhero DNA into their own DNA sequence to create a superhero. NOTE: There are two restriction enzyme sites in the DNA sequence: Ava II and EcoRI. Students will be able to cut their DNA at whichever restriction enzyme site they choose. When students finish, have them share in their teams what superhero trait they chose.

Closure

5. **Create a genetically modified organism.** Conclude this lesson by having the students genetically modify a hypothetical organism for a maximum of two foreign traits that will benefit the world somehow. Students will draw this new organism, identify the new traits and what species they were obtained from, explain why this new organism benefits the world and explain how this trait was obtained and placed into their organism.

6. **Revisit the T-Chart.** Have the students revisit their list of questions or required information they composed for their engineering design challenge. The students should work with their small teams to make changes or adjustments to their lists. They can add new information that they'd like to receive from the client and/or remove any information that they now feel that have adequate knowledge of.

7. **Connect to the engineering challenge. Ask:** *How do these activities help us in our engineering design challenge? How can plasmids and restriction enzymes be used to test if something is genetically modified?*

Assessments

Pre-Activity Assessment
During the demo, gauge student understanding of genetically engineered organisms based on the observations that they state and the discussion that they have.

Activity Embedded Assessment
During the *6.b. Gene Splicing* activity, circulate the room to ask students/teams questions and check observations in their notebooks.

Post-Activity Assessment
Review students' responses to *6.b. Gene Splicing* and drawing of a new genetically modified organism.

DUPLICATION MASTERS

- 6.b. Gene Splicing

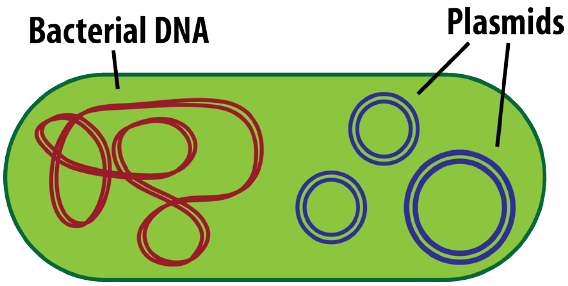
EDUCATOR RESOURCES

- 6.a. Gene Splicing Background

6.a. Gene Splicing Background

Inserting DNA into a Plasmid

Prokaryotic cells contain one large chromosome. This chromosome contains most of the DNA. Sometimes prokaryotic cells also have several small circular pieces of DNA called plasmids. These plasmids contain genes which code for proteins that are beneficial to the survival of the cell.



The first plasmids discovered contained genes for antibiotic resistance. Geneticists believe that plasmids contain these genes because they neutralize the action of an antibiotic on the bacterial cell. To counteract the effects of antibiotics which kill the bacteria, large quantities of the enzyme are required. More copies of the antibiotic-resistant gene that produces the enzyme can be carried on several plasmids than can be incorporated into one large chromosome.

Geneticists take advantage of prokaryotic plasmids by incorporating the DNA of a desired gene into the genome of the plasmid. When the plasmid replicates, the desired gene is also replicated. This way the information in the gene is passed from one generation to the next as the bacterial cell divides. More importantly, as the DNA in the plasmid is transcribed into mRNA, the desired DNA from the implanted gene also gets transcribed into mRNA so that translation can occur. Translation is when the mRNA is decoded to produce amino acids, which attach together to make the desired proteins.

Plasmids have been used in the process of gene splicing in a variety of study areas, including medicine and agriculture. To perform the necessary procedure that will place a piece of DNA into a plasmid, researchers use a restriction enzyme. A restriction enzyme is a specialized enzyme that cuts the DNA at a site where the base pairs are arranged in a specific order. For example, the restriction enzyme Bam HI cuts DNA between the two Gs in the sequence GGATCC.

```
G  GATCC
CCTAG  G
```

You may notice that the DNA is palindromic, which means the base pairs read the same each way, backward and forward. Since the structure of DNA is the same in all organisms, the same enzymes can be used in both prokaryotic and eukaryotic cells.

When geneticists want to insert a gene into another organism, they cut out the desired DNA from an organism using restriction enzymes. Using the same restriction enzyme, plasmids from a bacterial cell are cut in one spot to open it up. When DNA is cut, or spliced, this leaves the two open ends chemically active. These chemically active ends are called “sticky ends.” Because of DNA’s complimentary base-pairing rules, a sticky end will readily recombine with another piece of DNA with complimentary bases in order to chemically bond and once again become stable. When the new DNA is placed in with the cut plasmid, ligating enzymes are used to seal the new connection. It is possible for plasmids to recombine with themselves or with other compatible sticky ends to get a genome arrangement other than the one desired.

After the plasmid has been inserted into a bacterium, the scientist grows the bacterium on an agar plate to create the colony of bacteria with the new genotype. A selectable marker is used to identify the cells that have been transformed in the desired way.

LESSON 6

Name________________________ Date____________ Period _____

6.b. Gene Splicing (1/3)

You are a scientist and you want to become a superhero with your own set of superpowers. To do this, you must insert a piece of mutant superhero DNA into your own DNA sequence using restriction enzymes.

The superhero DNA has a restriction enzyme site that cuts DNA at the CAAG sequence. However, you need to cut your own DNA sequence in order to insert the mutant DNA and you do not know what restriction enzyme to use.

To cut your own DNA, you will use one of the following restriction enzymes, which cut at known nucleotide sites. Below is a chart of known Restriction Enzymes and where they cut the DNA sequence.

Ava II C | CTGG G | GACC	**Sac II** C | TCGAG G | AGCTC	**Hind II** T | TCGAA A | AGCTT
Bam HI G | GATCC C | CTAGG	**Hpa II** G | GCC C | CGG	**EcoR I** G | AATTC C | TTAAG

Instructions:

1. Cut out one DNA along the dotted lines and glue the two ends together so you form a ring.
2. Find a restriction enzyme cutting site in your own DNA sequence. When you find it, use scissors and carefully cut at the appropriate nucleotide of the restriction enzyme site.
3. Pick a superhero trait.
4. Cut your desired superhero trait along the mutant restriction enzyme site at the appropriate nucleotide.
5. Tape or glue your superhero trait into your own DNA sequence.
6. You have now created a genetically modified organism!

Name________________________________ Date____________ Period _____

LESSON 6

6.b. Gene Splicing (2/3)

Your DNA sequence

```
GCTTCGACTTGAACCCGGAATTCAACCTGGGATCGGATCGAATTTCAGATCGACTGGGATCGGATCGAATTTCAGATCGAATTTCAGATCGATTC
CGAAGCTGAACTTGGGCCTTAAGTTGGACCCTAGCCTAGCTTAAAGTCTAGCTGACCCTAGCCTAGCTTAAAGTCTAGCTTAAAGTCTAGCTAAG
```

```
GCTTCGACTTGAACCCGGAATTCAACCTGGGATCGGATCGAATTTCAGATCGACTGGGATCGGATCGAATTTCAGATCGAATTTCAGATCGATTC
CGAAGCTGAACTTGGGCCTTAAGTTGGACCCTAGCCTAGCTTAAAGTCTAGCTGACCCTAGCCTAGCTTAAAGTCTAGCTTAAAGTCTAGCTAAG
```

```
GCTTCGACTTGAACCCGGAATTCAACCTGGGATCGGATCGAATTTCAGATCGACTGGGATCGGATCGAATTTCAGATCGAATTTCAGATCGATTC
CGAAGCTGAACTTGGGCCTTAAGTTGGACCCTAGCCTAGCTTAAAGTCTAGCTGACCCTAGCCTAGCTTAAAGTCTAGCTTAAAGTCTAGCTAAG
```

```
GCTTCGACTTGAACCCGGAATTCAACCTGGGATCGGATCGAATTTCAGATCGACTGGGATCGGATCGAATTTCAGATCGAATTTCAGATCGATTC
CGAAGCTGAACTTGGGCCTTAAGTTGGACCCTAGCCTAGCTTAAAGTCTAGCTGACCCTAGCCTAGCTTAAAGTCTAGCTTAAAGTCTAGCTAAG
```

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GCTTCGACTTGAACCCGGAATTCAACCTGGGATCGGATCGAATTTCAGATCGACTGGGATCGGATCGAATTTCAGATCGAATTTCAGATCGATTC
CGAAGCTGAACTTGGGCCTTAAGTTGGACCCTAGCCTAGCTTAAAGTCTAGCTGACCCTAGCCTAGCTTAAAGTCTAGCTTAAAGTCTAGCTAAG
```

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GCTTCGACTTGAACCCGGAATTCAACCTGGGATCGGATCGAATTTCAGATCGACTGGGATCGGATCGAATTTCAGATCGAATTTCAGATCGATTC
CGAAGCTGAACTTGGGCCTTAAGTTGGACCCTAGCCTAGCTTAAAGTCTAGCTGACCCTAGCCTAGCTTAAAGTCTAGCTTAAAGTCTAGCTAAG
```

LESSON 6

Name______________________________ Date____________ Period _____

6.b. Gene Splicing

(3/3)

Superhero Trait	Gene Sequence		
Strength (immense strength)	AGCAAGATGC TCGTTCTACG	TCGCTAAGGCATAGCACG AGCGATTCCGTATCGTGC	TAGCAAGAATGCAGG ATCGTTCTTACGTCC
Flying (rise and move in air)	TAGCAAGAATGCGTCAT ATCGTTCTTACGCAGTA	TCGCTAAGGCAT AGCGATTCCGTA	AATAGCAAGAATGC TTATCGTTCTTACG
Speed (move at great speed)	GATTACAAGAG CTAATGTTCTC	AGGGCATAGCGATAT TCCCGTATCGCTATA	AGGGCATCAAGATAT TCCCGTAGTTCTATA
Telekinesis (move objects with mind)	GCACAAGTAATGC CGTGTTCATTACG	GCATAGCACGCTATTGCCTTAAGT CGTATCGTGCGATAACGGAATTCA	GCAAGAATGC CGTTCTTACG
Healing Factor (wounds heal at a fast rate)	TCAGAGCAAGAATGC AGTCTCGTTCTTACG	ATAGCACG TATCGTGC	ATGCTAGCAAGAATGC TACGATCGTTCTTACG
Time Travel (move through time and space continuum)	ATAGCAAGAATGC TATCGTTCTTACG	AAGGCATAGCACGGCCAA TTCCGTATCGTGCCGGTT	TATAGCAAGAATGC TAATCGTTCTTACG
Teleportation (move from one place to another)	TAGCAAGAATGC ATCGTTCTTACG	CGCTAAGCATAGCACG GCGATTCGTATCGTGC	AATAGCAAGAATGC TTATCGTTCTTACG
Invisibility (remain unseen)	GCAAGAGGCC CGTTCATCCGG	TCGCTAAGGCATAGCACG AGCGATTCCGTATCGTGC	TAGCAAGAATGC ATCGTTCTTACG
Fire Manipulation (control over fire)	ATAGCAAGATAATGC TATCGTTCTATTACG	CGCTAAGGCATAGCACG GCGATTCCGTATCGTGC	ACTAGCAAGAATGC TGATCGTTCTTACG
Telepathy (reads thoughts and communicates with mind)	TTGAGCAAGAATGC AACTCGTTCTTACG	TAATGCGCTAAGGCATAGCACG ATTACGCGATTCCGTATCGTGC	TAAAGCAAGAATGC ATTTCGTTCTTACG
Invincible (sustain no harm)	GCAAGAATGCTG CGTTCTTACGAC	TCGCTAAGGCATAGCACG AGCGATTCCGTATCGTGC	AAGGCAAGAATGC TTCCGTTCTTACG
Magnetic Manipulation (control magnetic fields)	CATATCAAGGC GTATAGTTCCG	GGCATAGATGCACG CCGTATCTACGTGC	GCGACAAGTTGG CGCTGTTCAACC
Atomic Manipulation (ability to reconstruct atoms)	CCTAGGTCAAGAATG GGATCCAGTTCTTAC	CACGTCGCTAAGGCATAGCACG GTGCAGCGATTCCGTATCGTGC	AACGCTTCAAGAATGC TTGCGAAGTTCTTACG

Restriction Enzyme "MUTANT" - cuts vertical line after sequence CAAG | GTTC |

LESSON 7

Designing a Solution

Lesson Objectives

Students will be able to:

- work toward the solution of a problem using engineering.
- develop and evaluate a plan acting as an engineer.
- describe the tradeoffs of an engineered design.
- justify why their solution is appropriate.

Time Required

two 45-minute class periods

Materials

Per classroom:

- EDP poster
- chart paper

Per student:

- engineering notebook
- pencil
- EDP slider

Standards Addressed

Next Generation Science Standards: MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, MS-ETS1-4

Key Terms

prototype, criteria, constraints, evidence-based reasoning

Lesson Summary

Students review the engineering challenge and use their knowledge of genes and heredity to brainstorm ideas on designs that describe how to prevent, sample and test whether GMO cross-contamination occurred. The challenge is to provide an accurate, reliable, and timely procedure that the farmers can utilize to assess cross-pollination. Students employ evidence-based reasoning as they choose their first prototype in order to justify all of their design decisions. They are then presented with a client letter that discusses the results of their testing strategy.

Background

Teacher Background

The great debate over GMO crops, also known as transgenic crops, continues in many circles of both the consumer and scientific worlds. Regardless of where you stand on this issue, farmers will be directly affected because some grain buyers establish a strict threshold for minimum GMO content in the grain they purchase. GMO “contamination” of non-GMO grain can occur in corn by virtue of either cross-pollination between adjacent fields of GMO and non-GMO hybrids or by commingling (a fancy term for “mixing”) of seeds. The latter can occur at planting time as farmers switch from planting one hybrid to another via seed carryover in the planter. Commingling can also occur during or after harvest time via grain mixing in the combine, trucks and wagons, drying facility or the storage facility. NOTE: Fortunately, cross-pollination is a negligible issue for self-pollinated crops like soybean. Because the potential exists for some grain buyers to limit their purchases of GMO corn, grain farmers should make plans now for minimizing the potential for GMO “contamination” of any non-GMO corn grain that they intend on producing.

Evidence-based Reasoning: Evidence-based reasoning (EBR) refers to the engineering practice of providing rationale for design ideas and decisions. It is somewhat similar to scientific argumentation in the sense that it involves using evidence and explanations to support a statement, but it is ultimately different. In EBR, the statement being supported is an engineering design idea or decision, whereas in scientific argumentation it is a claim or conclusion about a natural phenomenon. EBR is used in the context of generating solutions for engineering problems; scientific argumentation is used to answer scientific questions about nature. Science and mathematical principles are important justifications for scientific argumentation and EBR. However, EBR often also includes justifications related to the context, criteria, and constraints of the engineering problem (e.g., cost, user needs, technical feasibility). In this lesson, students will use EBR to think deeply about their proposed design ideas and to justify them with information about the engineering problem and their science and mathematics knowledge.

There will be two parts to this design challenge because not only will the students need to design a strategy to test whether cross-contamination occurred in the fields, but also a strategy to assess the effectiveness of the testing strategy. It is important to provide evidence-based reasoning when proposing a solution to a problem. In this example, the students will have to provide justifications for the design of their testing strategy, along with quantitative evidence supporting their strategy. Without the ability to provide reasoning, the explanation will not be enough for the client to accept it. This is an essential component of good science and engineering practices. There must be logic and data-based explanations for a solution. The individual or team that can provide the most convincing argument will be the one that the client accepts. There will be many different strategies identified to accomplish the desires of the client; however, a limited number of them will include a component that can be actually measured by the students. This reality will likely lead the students to conclude that building a prototype design may be the best method to determine the effectiveness of strategy. At the completion of the challenge, the students will be asked to defend their decisions and designs using their knowledge and understanding of the science content standards, their evidence from data collection, and their experiences using the engineering design process.

Before the Activity

On one poster-sized sheet of chart paper, draw an Evidence-Based Reasoning template (like worksheet *7.d.*) This will contain the explanations of the terms on the worksheets and what information goes in each section.

Make copies of the duplication masters:

- *7.a. Client Memo 2* (1 per student)
- *7.b. Planning Reflection Questions* (1 per student)
- *7.d. Modified Design Options* (1 per team)
- *7.e. Evidence-Based Reasoning* (1 per student)
- *7.j. Client Test Letters* (1 per team)
- *7.l. Test Solution Ideas* (1 per student)

Make copies of the *7.h. Teacher Observation protocol: Try* and *7.k. Teacher Observation Protocol: Test* (one for every four teams).

Classroom Instruction

Introduction

1. **Review the engineering challenge.** Share with students why the task is important. **Ask:** *What did we review in the GMO debate in the beginning of this unit?* Be sure to encourage them to think outside the box and the design and to use the knowledge they collected over the past several weeks. Provide the students with some time to reflect on what an engineer and engineering are.

2. **Identify where they are in the engineering design process. (Plan)** Direct students' attention to the Engineering Design Process poster and their Engineering Design Process sliders. **Say/Ask:** *As engineers, we have been using an engineering design process to guide us. What steps have we done so far?* Students should say that they have Defined the problem and Learned some science/background knowledge that will help them solve the problem. **Say:** *Now that we have defined our problem and learned background information about GMOs, we are ready start designing solutions to the problem. We can always go back to define and learn* (point to arrows on poster that show going back to previous steps)

Assessments

Pre-Activity Assessment
Monitor students' responses to the importance of the GMO debate activity and their reflection on engineers/engineering.

Activity Embedded Assessment
Check students' understanding through their verbal and written responses when deciding upon an idea and filling out the *7.e. Evidence-Based Reasoning* graphic. Walk around and assess teams progress using the *7.h. Teacher Observation Protocol: Try* and *7.k. Teacher Observation Protocol: Test*.

Post-Activity Assessment
Listen to students' responses about how they want to improve their solution. Use the *7.c. Planning Reflection Questions Rubric, 7.f. Evidence-Based Reasoning Rubric,* and *7.m. Test Solution Ideas Rubric* to evaluate students work.

DUPLICATION MASTERS

- 7.a. Client Memo 2
- 7.b. Planning Reflection Questions
- 7.d. Modified Design Options
- 7.e. Evidence-Based Reasoning
- 7.j. Client Test Letters
- 7.l. Test Solution Ideas

EDUCATOR RESOURCES

- 7.c. Planning Reflection Questions Rubric
- 7.f. Evidence-Based Reasoning Rubric
- 7.g. Evidence-Based Reasoning Instructions
- 7.h. Teacher Observation Protocol: Try
- 7.i. Detailed Design Options
- 7.k. Teacher Observation Protocol: Test
- 7.m. Test Solution Ideas Rubric

if we need to learn more about the problem or background information. For now, we will move on to the next step, which is to plan a solution.

3. **Read the client memo. Say:** *The client would like to provide more information for us to solve this engineering challenge.* Provide the *7.a. Client Memo 2* from the client who describes additional criteria and constraints for the engineering challenge.

Activity

4. **Brainstorm individually.** Explain that brainstorming is an important part of the engineering design process. **Say:** *The goal of brainstorming is to develop many different ideas so you have many to choose from. Not all of the ideas will be perfect, but you will be able to combine and adapt your ideas with your teammates' ideas to develop a team design that meets the criteria and constraints the client put forth.* Explain that students will work on their own to design a strategy to determine cross-contamination. Give students time to sketch their individual brainstormed ideas in their engineering notebooks. Require students to have more than one idea (at least 2) so that when they meet with their teams they will have a lot of ideas to pull from. Have students fill in the first question on *7.b. Planning Reflection Questions* or in their notebooks.

5. **Plan as a team**. Give the students time to work in their teams to brainstorm several ideas for solving the problem given by the client. Once they have done some brainstorming, provide them with the *7.d. Modified Design Options* to help them choose a testing strategy.

6. **Introduce evidence-based reasoning. Say:** *Now you have at least two different options your teams can use for your design strategy. As a team, you need to decide which plan you would like to use for your initial design. Scientists and engineers work hard to use evidence in making important decisions like this, so you're going to fill out an evidence-based reasoning graphic for each of your designs to help you decide which plan is the best.* Post an *7.e. Evidence-Based Reasoning* graphic template on the board or on a piece of poster paper. **Say:** *To help you with your planning, we are going to be using evidence-based reasoning. This means that you will need to support your design ideas with evidence and explanations. We will discuss each of the parts together.* Clarify with students that the *7.g. Evidence Based Reasoning Instructions "*poster with explanations" will have general explanations and reminders of what kind of information should go in each section. This is different from what the students will write in the templates. They will fill out the boxes with information specific to their engineering design problem.

7. **Review the engineering problem.** Direct students' attention to the problem including Criteria and Constraints" section of the *7.e. Evidence-Based Reasoning* graphic. On the poster, write down a general definition of the term problem: the engineering problem the client asked you to solve. Instruct students to write a summary of their engineering problem in this section, leaving room for criteria and constraints.

8. **Review the criteria and constraints of the problem. Ask:** *Can anyone remind me what the words "criteria" and "constraints" mean?* Criteria are the requirements, or goals, of the designed solutions. Constraints are things that limit design possibilities. Write these definitions on the EBR poster. Refer students back to their lists of criteria and constraints from their Define the Problem notes. **Ask:** *What are some of the criteria and constraints of our engineering problem?* Discuss the criteria and constraints of the problem, and have students write them in the "Problem including Criteria and Constraints" section of the *7.e. Evidence-Based Reasoning* graphic.

9. **Introduce the concept of simplifying assumptions. Say:** *Engineers usually don't deal with every single aspect of a problem at once because that makes the problem too difficult to solve. Instead, they make a complex problem simpler, sometimes by ignoring some of the details of the problem and sometimes by pretending certain things are true about the problem when they actually aren't.* Write "ways to make a complex problem simpler" in the "Simplifying Assumptions (if any)" section of the EBR poster. **Ask:** *What are some parts of our engineering problem that we can make simpler?* This may be a difficult concept for students, so provide an example or two if students struggle.
   - Simplifying assumptions (things to ignore): aesthetics/appearance, durability (how well it withstands wear and damage).
   - Simplifying assumptions (assume certain things are true when they aren't): materials used in classroom are similar to those the client has.

10. **Explain what information goes in each of the remaining sections.** Have students guess at what kind of information they think should go in the "Plan," "Data/Evidence," and "Explanation, Justification, Reasoning" sections of the *7.e. Evidence-Based Reasoning* graphic. Write down relevant student suggestions in the appropriate section of the EBR poster. This could include:
    - **Design Idea:** Description of the design idea; drawings of the design idea, possibly with different views (e.g., top view, side view); dimensions/sizes/angles; materials in the design idea labeled to show where they are used; interesting features of the design idea.
    - **Data/Evidence:** Observations and data that show why you think your design will work. Examples: data from the labs and simulations.
    - **Justification:** Complete sentences that state why you think your design will be successful. These sentences should refer to the problem, criteria, constraints, idea, and data/evidence.

11. **Complete evidence-based reasoning template.** Have the students begin the activity by working with their team to design. Distribute *7.e. Evidence-Based Reasoning* graphic to each student. Provide students time to complete the graphic with their teammates.

12. **Choose a prototype testing strategy.** Upon completing the *7.e. Evidence-Based Reasoning* graphics, direct teams to use this evidence to select one design. Have students answer the second question on the

7.b. Planning Reflection Questions worksheet. Tell them to consider that the testing strategy is going to be used by farmers so they will want to make sure that it is desirable for them to use. **Say:** *Remember to consider what factors might impact the success of your prototype based on what may be important for the farmers in terms of cost, accessibility, ease of use, effectiveness, and availability.* This process should incorporate current and available scientific processes. Proficiency in the content standards for genetics/heredity should be demonstrated through the process. The students should explain how the process utilizes science knowledge to identify GMO and non-GMO plants. Utilize the *7.h. Teacher Observation Protocol: Try* to assess students while they work.

13. **Identify where students are in the engineering design process. (Test)** Direct students' attention to the Engineering Design Process poster and their Engineering Design Process sliders. **Say/Ask:** *As engineers, we have been using an engineering design process to guide us. What steps have we done so far?* Students should say that they have defined the problem, learned some science/background knowledge that will help them solve the problem, and planned solutions. **Say:** *Now that we have defined our problem, learned background information about types of genetics and planned/designed solutions to the problem, we are ready to test. We can always go back to define and learn (point to arrows on poster that show going back to previous steps) if we need to learn more about the problem or background information. For now, we will move on to the next step, which is to test our design.*

14. **Provide feedback.** Have each team bring their initial prototype design to you so you can review it before giving them a client letter that discusses the results of their design strategy. Provide feedback for the students in terms of their design feasibility/practicality as needed, such as helping them identify areas that may be difficult for the farmers to implement. Use the *7.i. Detailed Design Options* to scaffold students in their design decisions. Lead a discussion on the pros/cons of each strategy (cost, turnaround time, and reliability).

15. **Test with mock data.** Have the students "test" their prototype design strategy by analyzing the *7.j. Client Test Letters*. Provide each team with respective results they would see with their testing strategy. Students should record observations as they test their strategy. Utilize the *7.k. Teacher Observation Protocol: Test* to assess student work. Instruct students to complete *7.l. Test Solution Ideas* and glue it in their engineering notebooks.

Closure

16. **Revisit the T-Chart.** Have the students revisit their list of questions or required information they composed for their engineering design challenge. The students should work with their small teams to make changes or adjustments to their lists. They can add new information that they'd like to receive from the client and/or remove any information that they now feel that have adequate knowledge of.

17. **Connect to the engineering challenge. Ask:** *Are you satisfied with your first design decision? What do you think could be improved for the client?* **Say:** *A critical part of engineering is to redesign, so start to think about how you can make your initial design more successful now that you have received data from your first design decision. Remember, the client would like to hear exactly what you know to scientifically justify your engineering design decisions. Take that into consideration while you plan your redesign.*

LESSON 7

Name________________________________ Date__________ Period _____

7.a. Client Memo 2

Dear Student Engineers,

The organic farmers thank you in your willingness to solve this engineering challenge. To assist in your brainstorming, we would like to provide you with the options available to the farmers to prevent, sample and test whether GMO cross-contamination occurred in their fields. Interestingly, we observed this GMO corn has a stunning yellow appearance and is sweet to the taste compared to organic corn. This information may prove useful in your design. Please choose the most efficient and effective strategy within these four categories: a prevention barrier, whether to test before or after pollination, how much sample to test, and the strategy to test for cross-pollination. Remember that we will take into consider the scientific justification for your decisions.

Thank you for your help!

James Randolf
Organic Outreach Coordinator
University of Minnesota, Agricultural Department

LESSON 7

Name________________________________ Date__________ Period _____

7.a. Client Memo 2

Dear Student Engineers,

The organic farmers thank you in your willingness to solve this engineering challenge. To assist in your brainstorming, we would like to provide you with the options available to the farmers to prevent, sample and test whether GMO cross-contamination occurred in their fields. Interestingly, we observed this GMO corn has a stunning yellow appearance and is sweet to the taste compared to organic corn. This information may prove useful in your design. Please choose the most efficient and effective strategy within these four categories: a prevention barrier, whether to test before or after pollination, how much sample to test, and the strategy to test for cross-pollination. Remember that we will take into consider the scientific justification for your decisions.

Thank you for your help!

James Randolf
Organic Outreach Coordinator
University of Minnesota, Agricultural Department

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LESSON 7

Name_______________________________________ Date____________ Period _____

7.b. Planning Reflection Questions

Directions: Please answer the following questions after your EBR graphics are complete.

1. What are the pros and cons of each of your own solution ideas?

2. Which solution did your team choose and why? Provide evidence for your reason.

Student Name________________________________ Date__________

7.c. Planning Reflection Questions Rubric

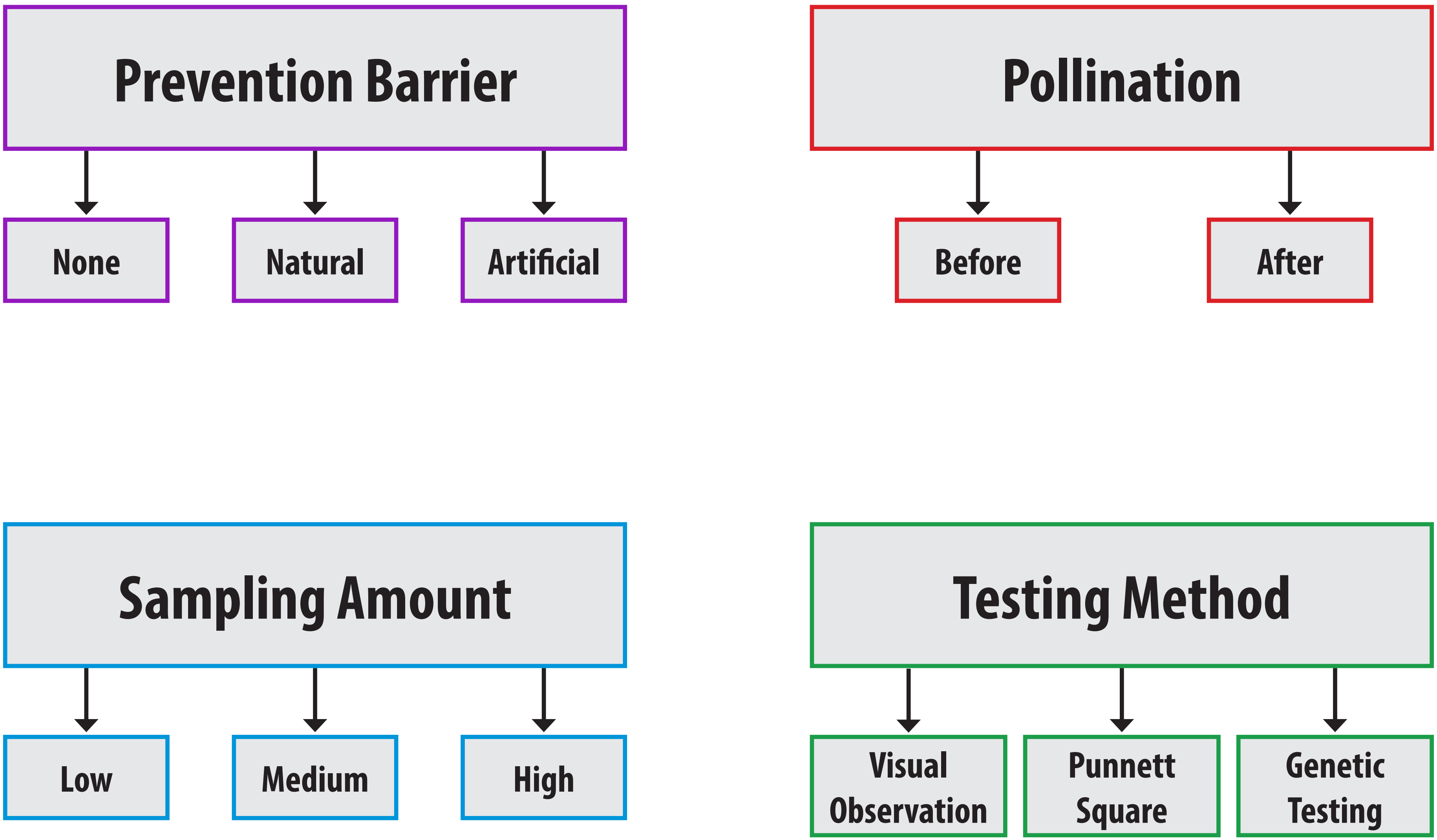
Problem	Question	Learning Objectives	Rubric	
7.b.1	What are the pros and cons of each of your own solution ideas?	Select potential solution through systematic evaluation of various solutions based on the problem.	yes no	**Provided at least 1 pro for each solution generated (as an individual)**
			yes no	**Provided at least 1 con for each solution generated (as an individual)**
7.b.2	Which solution did your team choose and why? Provide evidence for your reason.	Select potential solution through systematic evaluation of various solutions based on the problem.	yes no	**Stated which solution was chosen**
			yes no	**Provided an explanation for why the team chose that solution that was based on evidence**

Notes:

LESSON 7

Name_______________________ Date___________

7.d. Modified Design Options



LESSON 7

Name________________________________ Date___________ Period _____

7.e. Evidence-Based Reasoning (1/2)

Problem with Criteria & Constraints • Explain the client's problem that needs a solution and why it is important to solve. • List criteria and constraints you will use to decide if your solution is working.	
Problem: **Criteria:** **Constraints:**	
Simplifying Assumptions • List things that might be important but you have decided not to worry about.	
Design Idea #____ • Plan including drawing, labels of materials used, and labels of what each part does.	**Data/Evidence** • List science/mathematics learned and/or results of tests that support your design idea.

LESSON 7

Name________________________________ Date____________ Period _____

7.e. Evidence-Based Reasoning (2/2)

Justification - Why do you think this design idea will work? • Explain how your data and evidence support your design idea in order to meet criteria/constraints.

Student Name______________________________ Date__________ Period _____

7.f. Evidence-Based Reasoning Rubric

Section	Learning Objective	Rubric	
Problem	Explain the problem based on a synthesis of information. Explain why the problem is important to solve based on evidence that is relevant to the problem.	yes no	**Identified problem**
		yes no	**Explained why the problem is important**
Criteria	Explain criteria based on given information.	yes no	**Identified at least 1 criterion**
Constraints	Explain constraints based on information.	yes no	**Identified at least 1 constraint**
Simplifying Assumptions	Explain assumptions they have made in order to make solving the problem more manageable.	yes no	**Identified at least 1 simplifying assumption**
Design Idea	Communicate design idea including the parts of the design and how they interact.	yes no	**Included tests to be completed**
		yes no	**Included order of tests**
		yes no	**Communicated ideas clearly**
Data/Evidence (List math/science learned and/or results of tests that support your design idea)	Apply evidence gathered from testing to choose solution. Apply math/science concepts to choose solution.	yes no	**Listed at least 1 piece of valid evidence**
		yes no	**Evidence is from mathematics/science they have learned or from the results of the tests**
Justification (Explain how your data/evidence supports your design idea in order to meet criteria/constraints. Why do you think this will work?)	Justify why their design solution is appropriate based on application of core science/mathematics concepts. Justify why their design solution is appropriate based on information obtained in problem scoping.	yes no	**Included explanation of how their data/evidence supports their design idea**
		yes no	**Explained why this will work**
		yes no	**Explained how design idea will meet criteria/constraints**
Notes:			

7.g. Evidence Based Reasoning Instructions

Poster with Explanations

Problem with Criteria & Constraints
- Explain the client's problem that needs a solution and why it is important to solve.
- List criteria and constraints you will use to decide if your solution is working.

Problem: **the engineering problem the client asked you to solve**

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

Constraints: **things that limit design possibilities**

Simplifying Assumptions
- List things that might be important but you have decided not to worry about.

Ways to make a complex problem simpler

Design Idea #____ • Plan including all parts of the testing procedure, plus the order of the procedures.	**Data/Evidence** • List science/mathematics learned and/or results of tests that support your design idea.
• **This design idea is a process.** • **The process should be communicated in a clear way with all important aspects included.** • **If order of things matters to the process, make sure that your design idea makes order clear.** • **The communication of the process should be clear and understandable.**	**Observations and data that show why you think your design will work** **Examples:** • **Data from science and mathematics lessons, labs, and activities** • **Theoretical science/mathematics that provide reasons for choices they made**

Justification - Why do you think this design idea will work?
- Explain how your data and evidence support your design idea in order to meet criteria/constraints.

Complete sentences that state why it is possible that the design will be successful. These sentences should refer to the problem, criteria, constraints, idea, and data/evidence.

7.g. Evidence-based Reasoning Instructions

Got GMOs? Example

Problem with Criteria & Constraints
Problem with Criteria & Constraints • Explain the client's problem that needs a solution and why it is important to solve. • List criteria and constraints you will use to decide if your solution is working.
Problem: **The GMO crops are contaminating non-GMO fields.** **Criteria:** **Design must test whether GMO-contamination occurred. It needs to be an available method that is fast and reliable.** **Constraints:** **It must use available technology.**
Simplifying Assumptions • List things that might be important but you have decided not to worry about.
We do not need to worry about the aesthetics/appearance of the available tools. We also don't need to worry about how the tools are transported or the costs associated with each test.

Design Idea #____	Data/Evidence
• Plan including all parts of the testing procedure, plus the order of the procedures.	• List science/mathematics learned and/or results of tests that support your design idea.
Student plans will vary. See EBR poster for the type of information students should include in their plan.	**Student responses will vary. See EBR poster for the type of information students should include in their data/evidence.**

Justification - Why do you think this design idea will work?
• Explain how your data and evidence support your design idea in order to meet criteria/constraints.
Student responses will vary. See EBR poster for the type of information students should include in their explanation.

7.h. Teacher Observation Protocol: Try Lesson

Team #	All team members are on-task to make/try their solution.	One or more team members are not on-task.	Team has made appropriate progress on their solution.	Team is struggling to make their solution.	Team is making a solution directly related to problem.	Team is making something unrelated to problem.	Notes

Optional Question Prompts:

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

1. Can you tell me about your solution? What are you designing?
2. What were some of the other solution ideas you generated? How well did they address the problem?
3. How did you decide to move forward with this idea? What evidence do you have that your design will solve the problem for the client?

7.i. Detailed Design Options

Prevention Barrier

	None	Natural	Artificial
Cost:	0	$$	$$$
Reliability:	0	★★	★★★
Time:	0	🕒🕒🕒	🕒🕒🕒

Planting Season

	Off	On
Cost:	$	0
Reliability:	★★	0
Time:	🕒🕒	🕒

Sampling Amount

	Low	Medium	High
Cost:	$	$$	$$$
Reliability:	★	★★	★★★
Time:	🕒	🕒🕒	🕒🕒🕒

Testing Method

	Visual Observation	Punnett Square	Genetic Testing
Cost:	$	$$	$$$
Reliability:	★	★★	★★★
Time:	🕒🕒	🕒🕒🕒	🕒

LESSON 7

Name________________________________ Date___________ Period _____

7.j. Client Test Letters (1/4)

Dear Student Engineers,

Your proposal showed a great deal of thought and analysis into the problem. The University of Minnesota Agricultural Department recognized the work you put into studying the problem to submit a proposal. However, it is somewhat concerning that your preliminary design strategy may not have taken cost into consideration. Remember that you need to make difficult decisions and sacrifice other considerations in your final design (such as time or reliability).

Ultimately, the proposal included a somewhat limited design that may not have been able to explore all of the criteria and constraints. Please redesign your design strategy and provide further elaboration on the scientific justification behind your choices. We are looking forward to seeing what you develop.

Sincerely,

James Randolf
Organic Outreach Coordinator
University of Minnesota Agricultural Department

LESSON 7

Name________________________________ Date___________ Period _____

7.j. Client Test Letters (2/4)

Dear Student Engineers,

Your proposal showed a great deal of thought and analysis into the problem. The University of Minnesota Agricultural Department recognized the work you put into studying the problem to submit a proposal. However, it is somewhat concerning that your preliminary design strategy may not have taken reliability into consideration. Remember that you need to make difficult decisions and sacrifice other considerations in your final design (such as time or reliability).

Ultimately, the proposal included a somewhat limited design that may not have been able to explore all of the criteria and constraints. Please redesign your design strategy and provide further elaboration on the scientific justification behind your choices. We are looking forward to seeing what you develop.

Sincerely,

James Randolf
Organic Outreach Coordinator
University of Minnesota Agricultural Department

LESSON 7

Name_______________ Date_______ Period ____

7.j. Client Test Letters (3/4)

Dear Student Engineers,

Your proposal showed a great deal of thought and analysis into the problem. The University of Minnesota Agricultural Department recognized the work you put into studying the problem to submit a proposal. However, it is somewhat concerning that your preliminary design strategy may not have taken time into consideration. Remember that you need to make difficult decisions and sacrifice other considerations in your final design (such as time or reliability).

Ultimately, the proposal included a somewhat limited design that may not have been able to explore all of the criteria and constraints. Please redesign your design strategy and provide further elaboration on the scientific justification behind your choices. We are looking forward to seeing what you develop.

Sincerely,

James Randolf
Organic Outreach Coordinator
University of Minnesota Agricultural Department

LESSON 7

Name_______________ Date_______ Period ____

7.j. Client Test Letters (4/4)

Dear Student Engineers,

Your proposal showed a great deal of thought and analysis into the problem. The University of Minnesota Agricultural Department recognized the work you put into studying the problem to submit a proposal. However, it is somewhat concerning that your preliminary design strategy could use further scientific justification on your procedures. Remember that you need to make difficult decisions and sacrifice other considerations in your final design (such as time or reliability).

Ultimately, the proposal included a somewhat limited design that may not have been able to explore all of the criteria and constraints. Please redesign your design strategy and provide further elaboration on the scientific justification behind your choices. We are looking forward to seeing what you develop.

Sincerely,

James Randolf
Organic Outreach Coordinator
University of Minnesota Agricultural Department

7.k. Teacher Observation Protocol: Test Lesson

Team #	All team members are on-task to test solution.	One or more team members are not on-task.	Team has made appropriate progress on testing and analysis.	Team is struggling to test or analyze their solution.	Team has identified how to improve solution.	Team is struggling to consider improved performance.	Notes

Optional Question Prompts:

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

1. What did you find out from testing?
2. How did you interpret the findings from your tests? What do you think the results mean?
3. How did you decide what could improve your solution's performance?

LESSON 7

Name________________________________ Date___________ Period _____

7.I. Test Solution Ideas (1/2)

Section 1

Directions: Please answer the following questions about what you learned from your client letter.

1. What are the results of your client letter?

2. What have you learned about the performance of your solution from your client letter? Explain both the things that worked and did not work.

   My response:

   Team response:

3. What changes will you make to your solution based on the results of your client letter?

   My response:

   Team response:

4. Why will you make those changes? Think about the results of your client letter and the science and mathematics you have learned.

   My response:

   Team response:

Name________________________________ Date__________ Period _____

7.I. Test Solution Ideas (2/2)

Section 2

Directions: Please answer the following questions about the overall quality of your solution.

5. In what ways does your solution meet the criteria and constraints of the problem?

   My response:

   Team response:

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

   My response:

   Team response:

LESSON 7

Student Name________________________________ Date____________

7.m. Test Solution Ideas Rubric

Problem	Question	Learning Objectives	Rubric	
7.I.1	What were the results of your test(s)?	Analyze test results.	yes no	**Listed specific results of tests**
7.I.2-4	2. What have you learned about the performance of your solution from your test results? Explain both the things that worked and did not work. 3. What changes will you make to your solution based on the results of your tests? 4. Why will you make those changes? Think about the results of your tests and the mathematics and science you have learned.	Analyze test results. Apply evidence gathered through test analysis to improve the performance of chosen solution. Apply evidence gathered from testing to choose solution. Apply mathematics/science concepts to inform redesign.	yes no	**Explained advantages of solution found in tests**
			yes no	**Explained drawbacks of solution found in tests**
			yes no	**Listed planned improvements**
			yes no	**Explained rationale for improvements based on test results**
			yes no	**Explained rationale for improvements based on correct understanding of mathematics/ science**
7.I.5	In what ways does your solution meet criteria and constraints of the problem?	Evaluate the alignment between their proposed solution and the problem.	yes no	**Compared their solution to specified criteria and constraints**
7.I.6	In what ways does your solution not yet meet the criteria and constraints of the problem?	Evaluate the alignment between their proposed solution and the problem.	yes no	**Contrasted their solution to specified criteria and constraints**

Notes:

LESSON 8

Redesigning a Solution

Lesson Objectives

Students will be able to:

- use previous knowledge to create an improved design.
- work toward the solution of a problem using engineering.
- develop and evaluate a plan acting as an engineer.
- describe the tradeoffs of an engineered design.

Time Required

one 45-minute class periods

Materials

Per classroom:

- EDP poster

Per student:

- engineering notebook
- pencil
- EDP slider

Standards Addressed

Next Generation Science Standards: MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, MS-ETS1-4

Key Terms

prototype, criteria, constraints, evidence-based reasoning, redesign

Lesson Summary

Based on analysis of their initial designs, students work to improve and redesign their testing strategy, while incorporating the constraints of cost, reliability, and time. They then re-test and evaluate their new design, and decide which strategy is better.

Background

Teacher Background

Learning from failure: One of the most important aspects of engineering is learning from failure. Engineers often purposefully test models and prototypes until failure in order to better understand the limits of their designs. The engineers then use what they learned from this failure to redesign. Thus, in the engineering design process, it is important to continue beyond the first design cycle.

Redesign: After analyzing and evaluating their first prototype, students will begin to identify potential problems in the design, construction, organization, or cost of the original. At this point, some students will want to leap into a new design, others will insist on the success of their first prototype, while others may want to give up. The teacher can be a key factor in encouraging and guiding students through this transitional time. Because some students may be overly eager and want to skip the plan step of redesign, remind them of the importance of thinking through a design and creating written plans. For teams who are satisfied with their initial design's performance, encourage them to create a design that improves performance. For all teams, especially those who may want to give up, remind them that failing and then redesign is a key part of engineering and what professional engineers do. This is the stage in which students' understanding and skills are deepened and strengthened as they struggle with challenges and decisions. Learning from failure is not just an important skill for engineering, but it is also an important life skill. For redesign, encourage student teams that did not meet the main criteria to focus on meeting those criteria in their redesign. For teams that did meet the main criteria, encourage them to improve their design. Additionally, teams can think about other features that came up during defining the problem or testing the solution.

Before the Activity

Make copies of the duplication masters:

- *8.a. Assessment Rubric* (1 per team)
- *8.b. Detailed Design Options* (1 per team)
- *8.d. Assessment Rubric for Redesign* (1 per team)
- *8.e. Redesign Evaluation* (1 per student)

Evaluate students initial designs with the *8.a. Assessment Rubric*. This needs to be completed before the start of the lesson, as you will need to provide students with the evaluated rubric so the students are able to see how they need to improve their design. This will also be done with the *8.d. Assessment Rubric for Redesign* during the lesson once students have finished redesigning.

LESSON 8

Redesigning a Solution

The *8.b. Detailed Design Options* is the same worksheet as *7.i.* educator resource, but you will now provide this to students so they can scaffold their designs.

Make copies of the *8.c. Teacher Observation Protocol: Redesign* (one for every four teams). Make copies of the evaluation rubrics (*8.f.*) if you plan to hand them out to students with feedback (numbers vary). Feel free to put the feedback right in the notebooks based on the rubric information.

Classroom Instruction

Introduction

1. **Tie to the engineering challenge.** Have students explain the engineering problem that they have been trying to solve, including the criteria and constraints, as well as any modification they would make based on their initial prototype testing.

2. **Identify where they are in the engineering design process. (Decide)** Direct students' attention to the Engineering Design Process poster and their Engineering Design Process sliders. **Say/Ask:** *As engineers, we have been using an engineering design process to guide us. What steps have we done so far?* Students should say that they have Defined the problem and Learned some science/background knowledge that will help them solve the problem, designed solutions and tested their initial designs. **Say:** *Now that we have tested our initial design, we are ready to redesign to better suit the criteria and constraints. We can always go back to define and learn* (point to arrows on poster that show going back to previous steps) *if we need to learn more about the problem or background information. For now, we will move on to the next step, which is to decide and redesign.*

Activity

3. **Redesign. Say:** *Now that you have tried out your first prototype, I am going to provide you with the rubric to assess your initial prototype.* Provide students with their evaluated *8.a. Assessment Rubric,* as well as the *8.b. Detailed Design Options* to make decisions about their first prototype. Students should also consider any aspect of their prototype design that may not have been effective. For example, perhaps certain stages were not effective at assessing cross-pollination. Have the students draw their redesigned testing strategy into their engineering notebooks. **Say:** *You are going to have to make tough decisions based on the needs of your client. Your goal is to have the client choose your design, so be sure that you can justify why you made the choice you made, and that you can convince your client to use your design.* Have the students write out their redesigned testing strategy, while attempting to stay within the constraints. Every team should make changes to their testing strategy to make improvements. If a team does not feel like their prototype requires improvements, provide them with additional constraints to work with. Utilize the *8.c. Teacher Observation Protocol: Redesign* to assess student teams while they work.

Assessments

Pre-Activity Assessment
Check students' ability to explain the engineering problem and identify where they are in the EDP.

Activity Embedded Assessment
Monitor students' as they make decisions to redesign their testing strategy using the *8.c. Teacher Observation Protocol: Redesign.* Evaluate students redesigned solutions using the *8.d. Assessment Rubric for Redesign.*

Post-Activity Assessment
Evaluate students' responses on *8.e. Redesign Evaluation* using the *8.f. Redesign Evaluation Rubric.*

DUPLICATION MASTERS

- 8.a. Assessment Rubric
- 8.b. Detailed Design Options
- 8.d. Assessment Rubric for Redesign
- 8.e. Redesign Evaluation

EDUCATOR RESOURCES

- 8.c. Teacher Observation Protocol: Redesign
- 8.f. Redesign Evaluation Rubric

4. **Evaluate the redesign.** Once students have finished their redesign, score them with the *8.d. Assessment Rubric for Redesign*. Have them compare the new score to their old, and adjust their score accordingly. Have students fill out the *8.e. Redesign Evaluation*.

Closure

5. **Revisit the T-Chart.** Have the students revisit their list of questions or required information they composed for their engineering design challenge. The students should work with their small teams to make changes or adjustments to their lists. They can add new information that they'd like to receive from the client and/or remove any information that they now feel that have adequate knowledge of.

6. **Connect to the engineering challenge. Ask:** *Are you satisfied with your redesign?* **Say:** *Now you need to consider how to communicate your design decisions to the client, whether that be your initial design or your redesign. Remember the client wants you to justify your decisions using science and engineering principles.*

LESSON 8

Redesigning a Solution

LESSON 8

Name________________________________ Date___________ Period _____

8.a. Assessment Rubric

Reliability	Very reliable	Slightly reliable	Low reliability	Not reliable
	5 points	3 points	1 point	0 points
Turnaround Time	Very quick	Moderate	Long	Very long
	5 points	3 points	1 point	0 points
Cost	No cost	Little cost	Moderate cost	High cost
	5 points	3 points	1 point	0 points
Science Reasoning	The proposal demonstrates an understanding of the science content (genetics, heredity)	The proposal mostly demonstrates an understanding of the science content (genetics, heredity)	The proposal partially demonstrates an understanding of the science content (genetics, heredity)	The proposal does not demonstrates an understanding of the science content (genetics, heredity)
	10 points	6 points	2 point	0 points

Total: ______/25

Name________________ Date__________ Period_____

8.b. Detailed Design Options

Prevention Barrier

	None	Natural	Artificial
Cost:	0	$$	$$$
Reliability:	0	★★	★★★
Time:	0	◷◷◷	◷◷◷

Pollination

	Before	After
Cost:	$	0
Reliability:	★★	0
Time:	◷◷	◷

Sampling Amount

	Low	Medium	High
Cost:	$	$$	$$$
Reliability:	★	★★	★★★
Time:	◷	◷◷	◷◷◷

Testing Method

	Visual Observation	Punnett Square	Genetic Testing
Cost:	$	$$	$$$
Reliability:	★	★★	★★★
Time:	◷ ◷	◷◷◷	◷

8.c. Teacher Observation Protocol: Redesign

Team #	All team members are on-task to retest their solution.	One or more team members are not on-task.	Team has attempted to improve the performance of their solution.	Unclear what has been done to improve their solution.	Notes

Optional Question Prompts:

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

1. Can you tell me about how you are working to improve your solution?
2. What were some of the other solution improvement ideas you generated?
3. How did you decide to move forward with this idea? What evidence do you have that your improved design will solve the problem for the client?

LESSON 8

Name______________________________ Date__________ Period _____

8.d. Assessment Rubric for Redesign

Reliability	Very reliable	Slightly reliable	Low reliability	Not reliable
	5 points	3 points	1 point	0 points
Turnaround Time	Very quick	Moderate	Long	Very long
	5 points	3 points	1 point	0 points
Cost	No cost	Little cost	Moderate cost	High cost
	5 points	3 points	1 point	0 points
Science Reasoning	The proposal demonstrates an understanding of the science content (genetics, heredity)	The proposal mostly demonstrates an understanding of the science content (genetics, heredity)	The proposal partially demonstrates an understanding of the science content (genetics, heredity)	The proposal does not demonstrates an understanding of the science content (genetics, heredity)
	10 points	6 points	3 point	0 points

Total: _____/25

Score Change for Redesign		Improved overall design score from 1st design to 2nd design	Maintained overall design score from 1st design to 2nd design	Decreased overall design score from 1st design to 2nd design
		3 points	1 point	0 points

Total: _____/28

LESSON 8

Name________________________________ Date___________ Period _____

8.e. Redesign Evaluation

Directions: Please answer the following questions about the overall quality of your solution.

1. What are the results of your test(s)?
   My response:

   Team response:

2. Did your redesign improve your solution? Why or why not?
   My response:

   Team response:

3. If you could do another redesign, how would you try to improve your solution?
   My response:

   Team response:

LESSON 8

Student Name______________________ Date__________ Period _____

8.f. Redesign Evaluation Rubric

Problem	Question	Learning Objectives	Rubric	
8.e.1	What were the results of your test(s)?	Test improved solution and reflect on test results.	yes no	**Listed specific results of tests**
8.e.2	Did your redesign improve your solution? Why or why not?	Test improved solution and reflect on test results.	yes no	**Answered question and provided reasons for improvement or no improvement.**
8.e.3	If you could do another redesign, how would you try to improve your solution?	Test improved solution and reflect on test results.	yes no	**Listed planned improvements**

Notes:

LESSON 9

Communicate with the Client

Lesson Objectives
Students will be able to:
- communicate their design through the use of evidence-based reasoning
- justify why their design is appropriate.

Time Required
one 45-minute class periods

Materials
Per classroom:
- EDP poster

Per student:
- engineering notebook
- pencil
- EDP slider

Standards Addressed
Next Generation Science Standards: MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, MS-ETS1-4

Key Terms
client, criteria, constraints, evidence-based reasoning

Lesson Summary
Students choose their best design strategy and justify their decisions in a presentation to the client. After the presentation, the students receive feedback from the client on their designs. The unit closes with a unit review and summative assessment to review what students have learned.

Background
Teacher Background
While students should be using evidence-based reasoning while writing their letters to or posters for the client, they do not necessarily have to fill out an Evidence-Based Reasoning sheet. It may be helpful to have copies of this sheet available if students want to use the template to write their ideas in before they write the letter or create the poster; students could also copy the template into their engineering notebooks. Additionally, have the Evidence-Based Reasoning explanations poster from lesson 8 posted to remind students what kinds of information they need to include (i.e., solution, evidence, explanation) in their letter to or poster for the client.

The communications to the client may take the form of letters or posters, depending on what works best for your classroom. Additionally, students may do the creation of this communication individually or in design teams.

Before the Activity
Make copies of the duplication masters:
- *9.b. Unit Reflection* (1 per student)
- *9.d. Unit Review* (1 per student)
- *9.e. Summative Assessment* (1 per student)

Make copies of the *9.a. Client Communication Rubric* (1 per team). Make copies of the evaluation rubric (*9.c.*) if you plan to hand them out to students with feedback (numbers vary). Feel free to put the feedback right in the notebooks based on the rubric information.

Classroom Instruction
Introduction
1. **Tie to the engineering challenge. Ask:** *As we are wrapping up our design challenge, can anyone remind me about the problem? Who was our client? What were the criteria and constraints for our design?*

2. **Identify where they are in the engineering design process. (Communication)** Direct students' attention to the Engineering Design Process poster and their Engineering Design Process sliders. **Say/Ask:** *As engineers, we have been using an engineering design process to guide us. What steps have we done so far?* **Say:** *Now that we have completed redesign, we are ready report back to the client.*

Activity
3. **Share designs.** Have the students share their designs and experiences using the engineering design process. Teams should share with one another their designs and justify their reasoning with evidence, as well as

share with the class.

4. **Communicate ideas to the client.** Have the students write a proposal to the farmers describing the specifications of the product they suggest, as well as the testing process that can be used to test the effectiveness of the containment strategy. The proposal should include:
   - A detailed sketch of the testing strategy.
   - A written explanation for how the process effectively assesses cross-pollination. Explanations should explicitly address how the product components help make it successful.
   - What science content helped them to choose their process.
   - An explanation of how their design effectively uses the science content to function properly.
   - An argument for why the farmers should choose their design over any other.

   Evaluate the student proposals using the *9.a. Client Communication Rubric.*

Closure

5. **Provide feedback from client.** Students will want the client to provide feedback. You should create a way for the client to communicate back to the class. This can be in the form of a final letter, etc. You can also have an outside adult role play the client.

6. **Reflect on the engineering design process.** Students should complete the *9.b. Unit Reflection* about the process they used. They may either answer the questions directly in their notebook, or glue in the worksheet. **Say:** *Please include in your reflection things that you felt went well, things that didn't go so well and what changes you would make to your design process the next time you attempt an engineering challenge.*

7. **Review the entire unit.** Have the students write a description of the connection between science and engineering in their notebooks, out the *9.u. Unit Review* and complete the *7.v. Summative Assessment*.

Assessments

Pre-Activity Assessment
Check students' ability to explain the problem, client, criteria, and constraints.

Activity Embedded Assessment
Evaluate teams' design proposal with the *9.a. Client Communication Rubric*.

Post-Activity Assessment
Review students' answers to the *9.d. Unit Review* and *9.e. Summative Assessmen*t. Evaluate students' responses to *9.b. Unit Reflection* using the *9.c. Unit Reflection Rubric*.

DUPLICATION MASTERS

- 9.b. Unit Reflection
- 9.d. Unit Review
- 9.e. Summative Assessment

EDUCATOR RESOURCES

- 9.a. Client Communication Rubric
- 9.c. Unit Reflection Rubric
- 9.f. Summative Assessment Answer Key

9.a. Client Communication Rubric

Name of students in team:____

____

Assign a score for each item in the rubric based on the students' presentation.

Description (Students...)	5 points	3 points	1 point	0 points
introduce themselves.				
summarize the client's problem including criteria and constraints.				
explain why it is important to prevent cross-contamination for the crops for the farmers.				
describe their solution to the problem.				
mention the cost of the process.				
mention the pros and cons.				
describe improvements made from previous design.				
explain why the design is chosen over their other design.				
show their process flow diagram.				
show data and evidence gathered and used in their design.				
justify their process design decisions using data/evidence.				
explain how engineering design process, including redesign, was used to develop their process design.				
all participate in the team presentation.				
demonstrate in-depth knowledge of the topic.				
thank the client for his time.				

Total: ______/75

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9.b. Unit Reflection

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

1. **How has your <u>understanding of the problem</u> changed during the design process?**
   - Look back to the places where you defined the problem in your engineering notebook.
   - Think about client needs, criteria/constraints, and science/mathematics needed to solve the problem.

   My response:

   Team response:

2. **How has your <u>understanding of how to design a solution</u> changed during the design process?**
   - Look back in your engineering notebook to see how you developed your solution throughout solving the problem.
   - Think about what you did and how you made decisions to solve the problem.

   My response:

   Team response:

Student Name______________________________ Date__________

9.c. Unit Reflection Rubric

Problem	Question	Learning Objectives	Rubric	
9.b.1	How has your <u>understanding of the problem</u> changed during the design process? • Look back to the places where you defined the problem in your engineering notebook. • Think about client needs, criteria/constraints, and science/mathematics needed to solve the problem.	Communicate how their understanding of the problem deepened through the design process.	yes no	**Explained how their understanding of the problem has changed**
			yes no	**Included at least 1 of client needs, criteria/constraints, and science/mathematics in their explanation**
9.b.2	How has your <u>understanding of how to design a solution</u> changed during the design process? • Look back in your engineering notebook to see how you developed your solution throughout solving the problem. • Think about what you did and how you made decisions to solve the problem.	Communicate how their understanding of how to design solutions changed through the design process.	yes no	**Explained how their understanding of the how to design a solution has changed**
			yes no	**Included at least 1 example from their experience or how they made decisions in their explanation**

Notes:

Name______________________________ Date__________ Period _____

9.d. Unit Review

Topic	What we learned
engineering design process	
Punnett squares	
probability	
DNA structure & function	
inheritance of traits	
cross-pollination of plants	
genetic modification	
asexual/sexual reproduction	
genes & alleles	

LESSON 9

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9.e. Summative Assessment (1/2)

1. Which type of molecule contains genetic information that is passed from parents to offspring?
   a. fat molecules
   b. DNA molecules
   c. protein molecules
   d. carbohydrate molecule

2. What is a gene?
   a. a unit of information that determines the traits of an organism
   b. part of the chloroplast involved in photosynthesis
   c. where an organisms gets its resources
   d. protects the cell from bacteria

3. Humans, dogs, and trees are all living things. In which of these organisms would you find DNA molecules?
   a. only in humans
   b. only in humans and dogs
   c. in humans, dogs, and trees
   d. DNA molecules are not found in any of these organisms

4. Which of the following represents the correct order from smallest to largest? The smallest should be listed first.
   a. an atom, a chromosome, a cell
   b. an atom, a cell, a chromosome
   c. a cell, an atom, a chromosome
   d. a cell, a chromosome, an atom

5. Which of the following could be affected by the information in the DNA molecules of an organism?
   a. Both an organism's physical characteristics and the function of the organism's cells.
   b. An organism's physical characteristics, but not the function of the organism's cells.
   c. The function of the organism's cells, but not the organism's physical characteristics.
   d. Neither an organism's physical characteristics nor the function of the organism's cells.

6. Where are DNA molecules found in an animal's body?
   a. Inside all types of cells in an animal's body.
   b. Inside an animal's body, but not inside any cells in an animal's body.
   c. Inside sex cells, but not inside any other types of cells in an animal's body.
   d. Inside blood cells, but not inside any other types of cells in an animal's body.

7. Twins are born. One is a boy and one is a girl. Which statement is correct about their genetic makeup?
   a. The boy and the girl inherit genetic material from the father only.
   b. The boy and girl inherit genetic material from the mother only.
   c. The boy and girl inherit genetic material from both parents.
   d. The boy inherits genetic material from the father only and the girl inherits it from the mother only.

Name________________________________ Date___________ Period _____

9.e. Summative Assessment (2/2)

8. Which of the following supports the claim that the environment can affect genetic traits?
   a. trees get taller as they grow
   b. flower color varies with soil pH
   c. plants are self pollinating
   d. pine trees bear cones every other year

9. Which of the following is an internal compartment that houses the cell's DNA?
   a. lysosome
   b. nucleus
   c. ribosome
   d. cell membrane

10. A mouse's tail gets caught in a mouse trap. When the mouse pulls free, its tail gets cut off. If the mouse has babies later, how will this affect the length of the tails of its babies?
   a. It will affect the length of the tails of all the babies.
   b. It will affect the length of the tails of some of the babies.
   c. It will not affect the length of the tails of any of the babies.
   d. It depends on how old the mouse was when its tail was cut off.

9.f. Summative Assessment Answer Key

1. Which type of molecule contains genetic information that is passed from parents to offspring?
   b. DNA molecules

2. What is a gene?
   a. a unit of information that determines the traits of an organism

3. Humans, dogs, and trees are all living things. In which of these organisms would you find DNA molecules?
   c. in humans, dogs, and trees

4. Which of the following represents the correct order from smallest to largest? The smallest should be listed first.
   a. an atom, a chromosome, a cell

5. Which of the following could be affected by the information in the DNA molecules of an organism?
   a. Both an organism's physical characteristics and the function of the organism's cells.

6. Where are DNA molecules found in an animal's body?
   a. Inside all types of cells in an animal's body.

7. Twins are born. One is a boy and one is a girl. Which statement is correct about their genetic makeup?
   c. The boy and girl inherit genetic material from both parents.

8. Which of the following supports the claim that the environment can affect genetic traits?
   b. flower color varies with soil pH

9. Which of the following is an internal compartment that houses the cell's DNA?
   b. nucleus

10. A mouse's tail gets caught in a mouse trap. When the mouse pulls free, its tail gets cut off. If the mouse has babies later, how will this affect the length of the tails of its babies?
    c. It will not affect the length of the tails of any of the babies.

Notebook Prompts and Titles

Teacher Directions:

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

Prompt title:
Question to answer

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

Problem Scoping Lessons - Define and Learn

Section 1:

Engineers:
What do engineers do?
Solve Problems:
How do engineers solve problems?

Section 2:

Questions for client:
What are at least 3 questions that you want to ask the client that will help you understand the problem better? Make sure to ask about all important aspects of the problem.

Section 3:

Client:
Who is the client?

Problem:

What is the client's problem that needs a solution? Explain why this is important to solve. Use information from your client to support your reasons.

End-users:
Who are the end-users?

Criteria:
What will make the solution effective (criteria)? Use detailed information you have from the client.

Constraints:
What will limit how you can solve the problem (constraints)? Use detailed information you have from the client.

What we need to learn:

Think about the problem of GMO cross contamination. In terms of determining if a non-GMO plant has been contaminated, what are at least 2 things you need to learn in order to designing a testing procedure for cross-contamination? Make sure to consider all important aspects of the problem. Be specific.

Generate Ideas/Plan Lessons

Section 1:

EBR Graphics can just be drawn in notebooks.

Section 2:

Have students answer the following after EBR graphics are complete.

Pros and Cons:
What are the pros and cons of each of your own solution ideas?

Why we chose our solution:
Which solution did your team choose and why? Provide evidence for your reason.

Test Solution Idea(s) Lessons

Section 1:

Ask students to complete after they have run their tests.

Test results:
What were the results of your test(s)?

Learned from test results:
What have you learned about the performance of your solution from your test results? Explain both the things that worked and did not work.

Changes from test results:
What changes will you make to your solution based on the results of your tests?

Reason for changes:
Why will you make those changes? Think about the results of your test and the science and mathematics you have learned.

Section 2:

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

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

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

Notebook Prompts and Titles

Redesign Lessons

Ask students to complete after they have run their redesign tests.

Test results:
What were the results of your test(s)?

Improvement?:
Did your redesign improve your solution? Why or why not?

Next ideas for improvement:
If you could do another redesign, how would you try to improve your solution?

Final Solution Lessons

Section 1:

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

Section 2:

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

Understanding of the problem:
How has your understanding of the problem changed during the design process?

- Look back to the places where you defined the problem in your engineering notebook.
- Think about client needs, criteria/constraints, and science/mathematics needed to solve the problem.

Understanding of designing a solution:
How has your understanding of how to design a solution changed during the design process?

- Look back in your engineering notebook to see how you developed your solution throughout solving the problem.
- Think about what you did and how you made decisions to solve the problem.

