EngrTEAMS

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

Landmine Detonation

Grades 5-6

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

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About EngrTEAMS

Purpose

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

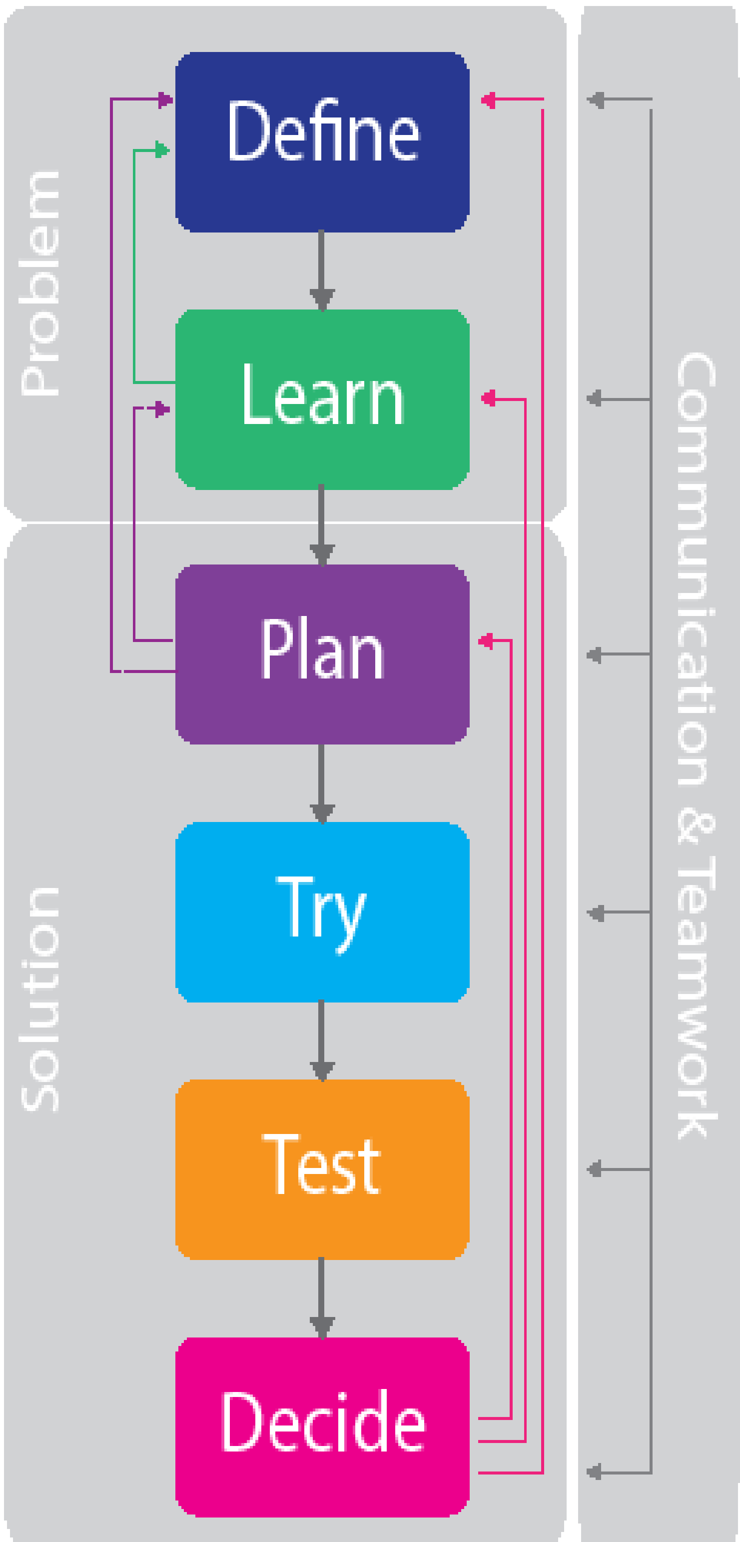
With a focus on vertical alignment and transition from upper elementary to middle-level, this project will impact at least 15,000 students over the life of the grant.

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

Overview

Engineering Design Process

A way to improve



Overview

DEFINE THE PROBLEM

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

LEARN ABOUT THE PROBLEM

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

PLAN A SOLUTION

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

TRY A SOLUTION

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

TEST A SOLUTION

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

DECIDE WHETHER SOLUTION IS GOOD ENOUGH

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

COMMUNICATION & TEAMWORK

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

Overview

Grade Levels: 5-6

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

Unit Summary

This unit is an exploration of levers through an engineering design challenge. The class has been asked by a company (Landmine Detonation Company) to create a launcher that can be used to safely detonate landmines that are still active.

Science Connections	Technology & Engineering Connections	Mathematics Connections
Levers, fulcrum, effort	The engineering design process, criteria, constraints	Data collection and analysis, variables, constants

Unit Standards

Next Generation Science Standards

- PS2.A Forces and Motion: The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.
- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
- MS-ETS1-4 Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.
- 3-PS2-1 Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

Common Core State Standards - Mathematics

- 5.MD.A.1 Convert among different-sized standard measurement units within a given measurement system (e.g., convert 5 cm to 0.05 m), and use these conversions in solving multi-step, real world problems.
- 5.MD.B.2 Make a line plot to display a data set of measurements in fractions of a unit ($\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$). Use operations on fractions for this grade to solve problems involving information presented in line plots.
- 6.SP.A.1 Recognize a statistical question as one that anticipates variability in the data related to the question and accounts for it in the answers.
- 6.SP.B4 Display numerical data in plots on a number line, including dot plots, histograms, and box plots.

Overview

Unit Assessment Summary

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

Overview

Lesson Summaries

Lesson 1: Save the Elephants

In this lesson students will be introduced to the problem of active landmines being in numerous places around the world. For this lesson, students will learn about a partnership with Landmine Detonation Company (LDC) through a client letter.

Lesson 2: Levers

In this lesson students will explore the simple machine (class 1 lever) that we will be using to examine the impacts of distance from the fulcrum and weight on effort. Students will explore how the effort changes based on the placement of where the effort is applied in relation to the fulcrum.

Lesson 3: Variable Sort Experiments

Students will be assigned one of the four variable sorts (it is fine if one is represented by more than 1 team). Students will work to control their experiment by only changing one variable. They will have a guide to follow to make sure that only one variable is changed, with agreed upon norms of how to collect the data and ensure that the entire experiment is kept controlled. They will collect data on their experiment and “share out” the data with classmates. Students will then graph the data to “share out” with the class.

Lesson 4: Planning and Building Launch Arm

Students will be given a 20 minute time constraint to plan their design for a launcher. The launcher will successfully launch a ping pong ball at least 2 meters, within 0.25 meters of the center of the target. This part of the engineering curriculum relies heavily on teamwork and conclusions from previous lessons on working with levers. Students will be given opportunities to write their ideas and decide on which idea will best represent the overall goal.

Lesson 5: Testing the Launcher

Students will get the opportunity to test their launcher model. They will learn how to collect the data and measure the distance from the target. Students will analyze their test data in order to make decisions about potential changes to their launcher model.

Lesson 6: Redesign and Testing with New Challenge

In the redesign challenge each team will get one additional constraint or criteria added to their requirements. In order to be successful they will have to accomplish one of the following:

- Launch 1 meter to within 10 centimeters of the center of the target.
- Launch 1.5 meters to within 15 centimeters of the center of the target.
- Launch 2 meters to within 20 centimeters of the center of the target.

Students will be required to work cooperatively in teams to plan out the redesign using evidence and data from previous investigations and from the results of the first test. Be sure to give plenty of time to build and test the new launcher. After the test, the students will evaluate the success of their model.

Overview

Lesson 7: Communication to LDC

Students will work in teams to communicate with LDC the overall problem, a claim on why their design is successful, evidence to support the claim, an explanation for why their design should be selected, and addressing any weaknesses in their design. Students should use evidence to support all claims. Students will be allowed to choose from a variety of methods that engineers use to communicate to their clients (memo, presentation, poster, etc.).

Overview

Lesson	Time Needed	Objectives The student will be able to:
1: Save the Elephants	One 50-minute class period	• Identify real world engineering problems. • Name the steps of the engineering design process. • Write an engineering problem in their own words.
2: Levers	Two 50-minute class periods	• Collect and organize data. • Graph data. • Use graphs to analyze data. • State how the placement of a load affects the amount of effort.
3: Variable Sort Experiments	Two 50-minute class periods	• Collect and organize data. • Graph and analyze data using plot.ly. • Communicate findings to the class for their variable.
4: Planning and Building Launch Arm	Two 50-minute class periods	• Collaborate with their team to design a ping pong ball launcher. • Collaborate with their team to build a ping pong ball launcher.
5:Testing Launcher	One 50-minute class period	• Work in teams to test model. • Analyze data for the tests of the ping pong ball laucher.
6: Redesign and Testing with New Challenge	Two 50-minute class periods	• Work in teams to redesign their model. • Redesign their launcher in order to meet new criteria.
7: Communication to LDC	One 50-minute class period	• Work in teams to create a communication to LDC. • Use evidence based reasoning to justify their design choices.

Overview

Materials * required materials not included in the kit	**Duplication Masters/ Educator Resources**
Per classroom: Computer with access to a projector **Per team:** none **Per student:** Engineering notebook*, Engineering design slider*, 2 different colored writing utensils*	• 1.a. Client Letter • 1.b. Engineering Notebook Questions • 1.a. Client Letter
Per classroom: Computer with access to a projector, chart paper poster (Post It Graph Paper) **Per team:** 1 fulcrum, 1 half-meter stick, 1 mass cube (load) with rubber band or hook, 1 spring scale with rubber band or hook **Per student:** Engineering notebook*, Engineering design slider*, Copy of Data Tables*, Notebook paper*	• 2.a. Data Table for Constant Mass
Per classroom: Computer with access to a projector, computer with access to plot.ly, chart paper poster (sticky note poster graph paper) **Per team:** 1 fulcrum, 1 half-meter stick, 1 mass cube (load) with rubber band or hook, 1 spring scale with rubber band or hook, copy of EBR Design Template* **Per student:** Engineering notebook*, engineering design slider*, copy of Data Tables*, notebook paper*, graph paper*	• 3.a. Evidence Based Reasoning • 3.b. Evidence-Based Reasoning - Poster with Explanation • 3.c. Data Table for Controlled Experiment
Per classroom: 1 Computer with access to a projector, 1 timer, duct tape, masking tape, painter's tape, paper plates, plastic cups, paper bowls, pipe cleaners, string, straws, craft sticks-regular, craft sticks-jumbo **Per team:** 1 meter stick, 1 half-meter stick, 2 1 ft rulers, 3 ping pong balls **Per student:** Engineering notebook*, engineering design slider*	• 4.a. Memo to LDC Rubric • 4.b. Teacher Observation Protocol: Try Lesson
Per classroom: Space for testing launching arms **Per team:** Launching model, measuring tape in meters, targets (suggested ground level cone), ping pong balls (3) **Per student:** Engineering notebook*, engineering design slider*	• 5.a. Teacher Observation Protocol: Test Lesson • 5.b. Evidence-Based Reasoning • 5.c. Evidence-Based Reasoning Poster • 5.d. Engineering Notebook Questions
Per classroom: 1 Computer with access to a projector., 1 timer, duct tape, masking tape, painter's tape, paper plates, plastic cups, paper bowls, pipe cleaners, string, straws, craft sticks-regular, craft sticks-jumbo **Per team:** 1 fulcrum, 1 meter stick, 1 half-meter stick, 1 1 ft ruler, 3 ping pong balls **Per student:** Engineering notebook*, engineering design slider*	• 6.a. Evidence-Based Reasoning • 6.b. Teacher Observation Protocol: Try Lesson • 6.c. Teacher Observation Protocol: Retest Lesson
• **Per classroom:** none • **Per team:** Data from previous lessons, laptop or iPad to type memo* (not required), poster paper* (not required) • **Per student:** Engineering notebooks*	• 7.a. Evidence-Based Reasoning • 7.b. Final Communication to LDC Rubric • 7.c. Engineering Notebook Questions

Overview

	Material	LessonsWhere Material is Used
Per classroom	1 computer with access to a projector 1 pack of targets (ground cones) 1 pack of chart paper Post-Its 1 timer 4 rolls of duct tape 6 rolls of masking tape 4 rolls of painter's tape Plastic cups* Small paper plates* Small paper bowls* Pipe cleaners* Tin foil* String* Straws* Craft sticks-regular* Craft sticks-jumbo*	1,2,3,4,5,6,7 5,6 2,3 4,6 4 4 4 4 4 4 4 4 4 4 4 4
Per team (assuming 3 students per team)	1 fulcrum 1 spring scale (with hook or rubber band) 1 mass cube (with hook) 1 gram weight set (with hook) 1 meter stick 1 half-meter stick 1 1 foot ruler measuring tape in meters 3 ping pong balls 2 rubber bands*	2,3,4,5 2,3 2,3 5,6 4,5,6 2,3,4,5,6 4,5,6 5,6 4,5,6 2,3,4,5,6
Per student	Engineering notebook* Notebook paper* Graph paper*	1,2,3,4,5,6,7 1,2,3,4,5,6,7 2,3

* required materials not included in the kit

LESSON 1

Save the Elephants

Lesson Objectives
The students will be able to:
- Identify real world engineering problems.
- Name the steps of the engineering design process.
- Write an engineering problem in their own words.

Time Required
One 50-minute class period

Materials
- **Per classroom:** Computer with access to a projector
- **Per team:** none
- **Per student:** Engineering notebook, Engineering design slider, 2 different colored writing utensils

Standards Addressed
- Next Generation Science Standards: MS-ETS1-1

Key Terms
engineering design process, landmine, simple machine

Lesson Summary
In this lesson students will be introduced to the problem of active landmines being in numerous places around the world. For this lesson, students will learn about a partnership with Landmine Detonation Company (LDC) through a client letter.

Background
Teacher Background
Students need to have completed prior work on teamwork strategies, specifically what it looks like and the qualities of a good team member. This should be displayed in the classroom and referenced often when working together. It will also be helpful for students to have prior knowledge of the engineering design process, but is not required. As each part of the process is implemented, the teacher can explain the step as thoroughly as is necessary for the class.

Before the Activity
- For added context, you may show the video at http://naturely.org/motala-elephant-prosthetic-leg/ during this lesson. However, this video is startling. Please preview this video to check that you find it appropriate for your students.

Classroom Instruction
Introduction to the unit:
1. **Introduce the unit. Say:** *We will be working on an engineering project related to saving people and animals from active landmines.*
2. **Introduce the Engineering Design Notebooks. Say:** *Engineers use notebooks to document their design process and keep notes. We will also be using Engineering Notebooks throughout our engineering challenge. Each day, you'll use the notebooks to take notes and record what you are learning. In addition, there are questions that you'll be asked to answer. Sometimes you'll answer the questions first on your own, then in your teams. Each day, turn in your engineering notebooks before you leave class.*

   Note: You can have your students write in their notebooks in two different colors – one for thoughts and prompts that are individual and one for thoughts and prompts that they discuss in their teams. This will help both you assess and the students recognize contribution of ideas. You also may want to have students complete a Notebook Cover and start a Table of Contents page. You may choose to have students tape/glue copies of the notebook prompts and/or the duplication masters into their notebooks.
3. **Students individually complete notebook prompts about engineering.** Have students individually answer the following 2 prompts in their notebooks prior to teaching them anything else about the unit or about engineering. Make sure to let them know that it is okay if they do not know very much about engineers or engineering – just have them answer the questions to the best of their ability. (1) *What do engineers do?* (2) *How do engineers solve problems?*

LESSON 1

Save the Elephants

Introduction

1. **Discuss responses to notebook prompts. Say:** *We are going to be working as engineers over the next few days. Turn and talk with your partner, "what do engineers do?"* Let students discuss then guide students to the following definition: Engineers are people who use science and mathematics to provide creative solutions to problems.
2. **Discuss technology**. Have students turn and talk with their partner(s) regarding the question, "What is technology?" Lead a discussion eventually guiding students to the following definition: Technology is something that has been created to solve a problem.
3. **Provide an overview of the engineering design process. Say:** *Because the problems that engineers solve are often difficult, they use a process to ensure that they do not miss anything important.* Introduce students to the engineering design slider. Give an overview of the engineering design process (see front matter for more information). **Say:** *Today we are going to be given a problem that we will work to solve as engineers.*

Activity

1. **Provide information about the design challenge. Say:** *We have been partnered with Landmine Detonation Company (LDC). LDC works to save lives by the removal and destruction of landmines that have been left in areas of conflict (war). There are numerous areas around the world that have been left with buried landmines close to surrounding villages. There are so many landmines that experts have said that it is as if a plane load of mines was dropped every 8 minutes, 24 hours a day, for 9 years. Many local people in areas like Laos have volunteered themselves or their animals to deactivate the tremendous amount of landmines. However, during this process, many animals and people have been injured or killed.*
2. **Watch video.** Show video http://naturely.org/motala-elephant-prosthetic-leg/. See note in "Before the Activity".
3. **Provide the client letter to students.** Connect the video to the problem through appropriate class discussion and bring students back to problem with the LDC client letter (*1.a. Client Letter*). Have students identify the problem in their own words.
4. **Develop questions for the client.** Have students think about what additional client information they will need to solve the problem. Ask students to answer the following question in their engineering notebook both individually and then in their teams, *What questions do you want to ask the client?*
5. **Ask questions to the client.** As a class, have students ask their questions to the client. Answer the questions representing the client. The following represent some of the information from the client regarding their launcher models. Answer other questions as you see fit to help the students to not get sidetracked by an off-topic idea.
    - Projectile: ping pong ball
    - Target will be at 2 meters from the launcher.
    - Ping pong ball must hit within ¼ meter of the center of the target.
    - Launcher is made from:
        - Provided fulcrum

Assessments

Pre-Activity Assessment

- Have students respond to "What do engineers do?" and "How do engineers solve problems?" individually in their engineering notebooks and then have them share out as a class. A working definition of engineering should be created.
- Students discuss with a partner and then as a class, "What is technology?" A working definition of technology should be created.

Activity Embedded Assessment

- Students discuss the problem and share their questions for the client. Students record their individual and team responses to the provided Engineering Notebook Questions in their notebooks.

Post-Activity Assessment

- Students record the engineering problem the client is asking them to solve in their own words in their engineering notebook.
- Check in with students about which step of the engineering design process they are in currently. (define/learn) Use the Engineering Design Process Slider as a tool for quickly assessing student understanding

DUPLICATION MASTERS

- 1.a. Client Letter

EDUCATOR RESOURCES

- 1.b. Engineering Notebook Questions

    - One launching arm choice (1 meter stick, 1 half-meter stick, or 1 1-foot ruler)
    - Something students design to hold the ping pong ball
    - Materials for holder: paper plates, plastic cups, paper bowls, pipe cleaners, string, straws, craft sticks-regular, craft sticks-jumbo
  - There is a time limit to build.
6. **Answer notebook questions individually.** Have students individually answer the questions from *1.b. Engineering Notebook Questions* in their engineering notebooks. You can either post these so students can see them (see appendix for titles) or copy them and have students attach them in their notebooks.
7. **Answer notebook prompts in teams and discuss.** Have students share and discuss their answers in their teams. They should use a different colored utensil to write their team's answer in their engineering notebook. Team ideas are "shared out" to the entire class. Document all ideas to show knowledge of the engineering problem they will be investigating.

Closure
1. **Tie to engineering design.** Bring the discussion back to the client letter and review what they have learned. **Ask:** *Based on what we have discussed today, where do you think we are in the engineering design process now?* (Define)
2. **Collect notebooks.** Make sure to keep the notebooks in the classroom.

Save the Elephants

LESSON 1

LESSON 1

Name________________________________ Date___________ Period _____

1.a. Client Letter

Landmine Detonation Company, INC
1000 Avenue G
Minneapolis, MN 55400

May 12, 2016

Dear Engineering Team,

There is a terrible danger in some countries from active landmines that have been left behind after conflicts. Our company would like to detonate dangerous landmines so that people and animals can be safe to travel through these areas.

We would like your help in creating a launcher that can detonate the landmines from a safe distance. You will be creating a model for the launcher. If you can create a model that will accurately detonate a landmine from 2 m away, then we will be able to create a full sized launcher that will safely detonate the landmines.

This is a humanitarian project that will change the lives of many people and animals. We really appreciate your hard work in helping to eliminate this problem.

Thank you,

Landmine Detonation Company, INC

1.b. Engineering Notebook Questions

Define and Learn Questions

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. **Who is the client?**
   My response:

   Team response:

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

   Team response:

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

   Team response:

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

   Team response:

1.b. Engineering Notebook Questions

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

   Team response:

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

   Team response:

7. **Think about the problem of active landmines and accidental detonation. In terms of launching an item to detonate the landmines, what do you need to learn in order to create a successful launch?**
   My response:

   Team response:

LESSON 2

Levers

Lesson Objectives
The students will be able to:
- Collect and organize data.
- Graph data.
- Use graphs to analyze data.
- State how the placement of a load affects the amount of effort.

Time Required
Two 50-minute class periods

Materials
- **Per classroom:** Computer with access to a projector, chart paper poster (grided)
- **Per team:** 1 fulcrum, 1 half-meter stick, 1 mass cube (load) with rubber band or hook, 1 spring scale with rubber band or hook
- **Per student:** Engineering notebook, Engineering design slider, Notebook paper

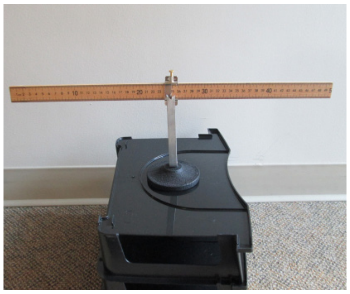
Standards Addressed
- Next Generation Science Standards: MS-ETS1-4
- Common Core State Standards – Mathematics: 6.SP.A.1

Key Terms
simple machine, fulcrum, variable

Lesson Summary
In this lesson students will explore the simple machine (1st class lever) that we will be using to examine the impacts of distance from the fulcrum and weight on effort. Students will explore how the effort changes based on the placement of where the effort is applied in relation to the fulcrum.

Background
Teacher Background
Students will need to have the background on their engineering problem. The teacher will need an understanding of and experience with basic levers. The teacher should try the activity ahead of time so that they are familiar with the variables in the system.

Before the Activity
The teacher should gather the materials and place them in a designated area for students to pick up when they are ready to begin the activity. Set up a fulcrum as an example for the students (see picture).



Classroom Instruction
Introduction
1. **Review the problem:** Review the problem that was discussed in the last lesson and formulated as a class. **Say:** *LDC is hiring us to create a model that can safely detonate landmines without further injuring people or animals.*
2. **Introduce simple machines. Say:** *I talked with LDC after we met last time. They told me they would like us to use simple machines in our model.* **Ask** students if they have ever heard this term. **Ask:** *What do you think of when you think of machines? What makes a machine a simple machine?*
3. **Provide pictures of simple machines.** Show students some pictures of different simple machines. As you show the pictures, ask the students to record what they notice in their engineering notebooks.
4. **Connect to the challenge. Say:** *LDC has communicated that they will be using levers for this design challenge. In order to be successful with this type of challenge, we will need to experiment with a lever in order to familiarize ourselves with how levers work. Remember, LDC is hiring us and they are requesting that we use a lever.*
5. **Tie to engineering design process. Ask:** *What do you think we need to do to prepare ourselves to use levers in our model?* Take student answers. Lead them toward learning about levers and how they work. **Ask:** *Where do you think this puts us in the engineering design process?* (Learn)

Activity: Day 1
Note: Over the next two days, students will be working with a team to collect, graph, and analyze data. The activity will involve experimenting with how the placement of the load will affect the amount of effort needed to balance out the lever. The students will also experiment with changing other variables in the system.

1. **Introduce the activity.** Tell students that they are going to be experimenting with levers. **Ask:** *Why do you think this will help us design*

our model for detonating landmines to help protect people and animals? Help them connect this experiment to the engineering challenge.

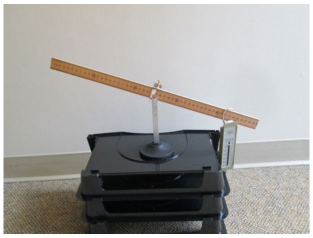
2. **Explore spring scales.** Pass out spring scales to each team. Have the students explore the spring scale in order to determine how it works and what is being measured. Have the teams "share out" their findings including a discussion of the measurement units. Go through several practice situations as a class. Have the students each practice reading the spring scale.
3. **Introduce the students to the rest of the materials needed to complete the activity.** Walk students through the materials and be sure to use the vocabulary (fulcrum, load, lever, effort,...). Allow the students time to explore the materials before they start taking measurements for the data table. In particular, be sure to give students time to explore the lever set up.
4. **Provide the details of the experiment.** Pass out the data table the students will be completing in order to keep their information organized (2*.a. Data Table for Constant Mass*). Explain that the students will be collecting data in order to determine how much effort (force in Newtons) is needed to lift the load (mass cube) while the effort is placed on various points of the lever arm. Each team will place the same load at 10 cm. Starting off with the effort at 2.5 cm, students will record how much effort is needed to balance the lever. They will then move the effort incrementally up to 25 cm, using the distances on the data table, recording the effort for each new placement. At this point, they are only filling out the column labeled Effort (N).

   Note: Students may struggle with the *2.a. Data Table for Constant Mass* worksheet. You may want to provide a detailed demonstration/ explanation of how to fill out the table and continued support while students are working.
5. **Conduct experiment.** Once they are finished, the students should clean up their spaces and record their results on the large class chart paper poster (grided).
6. **Exit slip.** Have students respond to, "What surprises you about the data? Why do you think that happened?" on a piece of notebook paper and turn it in.

Note: You will need to prepare graphs of the data collected in Day 1. Be sure to make the correction to each data point for the spring scale force before graphing them (see number 8 in day 2 for more details on how to determine the correction and why this is needed). Present the data as both a scatter plot and a bar graph.

Activity: Day 2

7. **Revisit the exit slips that were collected the previous day.** Discuss with the class the general surprises they saw in the data.
8. **Help students correct the data they collected.** Set the lever up where all the students can see. Hang a spring scale on one end of the lever (see picture). **Ask:** *What happened to the lever when I*



Assessments

Pre-Activity Assessment

- Day 1: Have students share what they think of when they think about machines and what makes a machine a simple machine. Show students pictures of several simple machines. Have them record their observations in their engineering notebooks.
- Day 1 & 2: Ask students about which step of the engineering design process they are in currently. (learn) Use the Engineering Design Process Slider as a tool for quickly assessing student understanding.

Activity Embedded Assessment

- Day 1: Observe students as they conduct the experiment and collect and record the results of their tests in the data table.
- Day 2: Assess notebook prompts for correct understanding of content and claim/evidence argument.

Post-Activity Assessment

- Day 1: Exit slip: Have students write what surprised them in the data and why they think that happened.
- Day 2: none

DUPLICATION MASTERS

- 2.a. Data Table for Constant Mass

EDUCATOR RESOURCES

- none

hung this spring scale on one end? (The lever is no longer balanced.) Have one student to come up and read how much the spring scale is reading when it is on the half-meter stick alone (It should measure 0 N). **Ask:** *How do you know that the spring scale is putting force other than 0 N on the lever?* (The lever is not balanced, so there is more force on the side that is down.) **Ask:** *How do you think we can measure how much force the spring scale is putting on the half-meter stick?* (Take answers. Eventually you should get to the idea that you could use another spring scale. Clear the lever of all spring scales. Put a spring scale on one side of the lever, which will make it tip. Be sure that all the students see the tipped lever. Remove that spring scale from the lever. Hang a second spring scale from the first so that you can measure the effort to hold a spring scale.The measuring spring scale should read close to 0.5 N - depending on what brand spring scale you use.) **Ask:** *How does this information impact the data collected yesterday?* (Take answers. In the end, they should understand that they need to add 0.5 N (or the amount you measured in class) to all of the results from yesterday. This is because the weight of the spring scale and the force one pulls on the scale each play a role in balancing the lever when the mass is on the other side. So you add the force read from the spring scale and the weight of the spring scale in N.) Have students fill in the second column of the *2.a. Data Table for Constant Mass* sheet. All entries here will be the same (the force of the spring scale).

> **Note:** This may bring up issues of mass versus weight if the students recognize that the mass cube is measured in grams. While the standards at this grade level do not require this differentiation, you will want to address this if it comes up.

9. **Finish the correction on the data table.** Students complete the final column in the data table on the sheet *2.a. Data Table for Constant Mass*. They should add the first and second columns to get the Corrected Effort for the third column.
10. **Consider multiple representations of data.** Ask students to discuss in teams other ways to represent the data besides just the list of numbers. "Share out" responses, compare and contrast the different representations discussed. Make sure to address graphs in this discussion.
11. **Compare graph types for data.** Pass out the graphs that were made from the data that were collected yesterday. Present the data as both a scatter plot and a bar graph. **Ask:** *What pattern do you notice when looking at the graphs?* Have the students compare and contrast the graphs in their teams.

    > **Note:** A bar graph is not an appropriate representation for this type of data. Bar graphs are meant for categorical data. These data are scalar. Use this comparison as a way to discuss the appropriateness of certain types of graphs.

12. **Use data to make a prediction.** Have students consider the following: *Based on your data, what force would it take to balance the load if you place the spring scale at 12.5 cm from the fulcrum?* Do not let students measure this. In their engineering notebooks, have them make a prediction and justify their prediction using their data as evidence. Verify students' predictions with a measurement.
13. **Fill in notebook prompt.** Have each student individually complete the following sentence in their notebook: As you move the effort away from the

fulcrum, the amount of effort _______________. (decreases) You can use this for assessment.

14. **Discuss claims and provide evidence for claim in notebook.** Have a few students "share out" what they recorded in their notebooks. **Say:** *We have made a claim about what we have noticed, and the evidence supports our claim. Scientists lose their credibility without evidence to support their claims.* **Ask:** *What evidence do you have that your claim is true?* Take student answers. Look for evidence such as students talking about the results of the experiment using data or the physical set up. As a class, model and discuss how they can support their claim with evidence from the data. Lead the students to how important the scatter plots are for visually representing the data.
15. **Summarize findings. Say:** *We have concluded that as we move the effort away from the fulcrum, the amount of effort increases. Looking at our activity, can you think of other ways we could use it to collect new information?* Ask students to think silently and record their ideas. Then have students "share out" to their teams. Then have the teams "share out" to the classroom while you record their ideas.

Closure

1. **Tie to engineering challenge. Ask:** *What did we learn that might be useful for detonating the active landmines?* Take answers. Lead a conversation about the usefulness of levers for launching things.
2. **Tie to next lesson on variable exploration.** Have the students consider the different variables that can be measured in the lever activity. **Ask:** *What are the different variables that can be measured on our levers?* (fulcrum position, mass load, position of load, length of lever). Assign each variable a spot in the classroom. Have the students pick the variable that they think will have the largest impact on the machine when tested. Have the students get up and move to the space of the room that represents each of the four possibilities. Have some students from each team "share out" the reason for their decision.

LESSON 2

Name________________________________ Date___________ Period _____

2.a. Data Table for Constant Mass

10 cm from Fulcrum

Mass of load (g): ___________

Position of Spring Scale from Fulcrum	Effort (N)	Spring Scale Weight (N)	Corrected Effort (N)
2.5 cm		_______ N	
5.0 cm		_______ N	
10.0 cm		_______ N	
15.0 cm		_______ N	
20.0 cm		_______ N	
25.0 cm		_______ N	

LESSON 3

Variable Sort Experiments

Lesson Objectives
The students will be able to:
- Collect and organize data.
- Graph and analyze data using plot.ly.
- Communicate findings to the class for their assigned variable.

Time Required
Two 50-minute class periods

Materials
Per classroom
- Computer with access to a projector, computer with access to plot.ly, chart paper poster (Post It Graph Paper)

Per team
- 1 fulcrum, 1 half-meter stick, 1 mass cube (load) with rubber band or hook, 1 spring scale with rubber band or hook, copy of EBR Design Template*

Per student
- Engineering notebook*, engineering design slider*, copy of Data Tables*, notebook paper*, graph paper*

Standards Addressed
- Next Generation Science Standards: 3-PS2-1
- Common Core State Standards – Mathematics: 6.SP.B.4

Key Terms
effort, load, Newton

Lesson Summary
Students will be assigned one of the three variable sorts (it is fine if one variable is represented by more than 1 team). Students will work to control their experiment by only changing one variable and design the experiment. They will collect data on their experiment and "share out" the data with classmates. Students will plot their graphs using an online tool, plot.ly, to "share out" with the class.

Background
Teacher Background
When testing variables, there will be times where it appears the lever does not require any effort to balance. This is relevant data that should be collected and noted. Rather than recording a number, have those students record an observation or summary of what they observed for that specific instance. An example of this is when the fulcrum is very close to the load.

We suggest ending the first day after the completion of the experiment. Then the second day the students can record their claims and evidence, create graphs using plot.ly, and "share out."

Before the Activity
The teacher should prepare all the materials that students will need in order to complete their controlled experiment. In this lesson, the teacher will be using plot.ly with students. It is suggested to create a class account that can be used to save their graphs for referencing later. Be sure to share the username and password with the students.

Classroom Instruction
Introduction
1. **Tie to engineering challenge.** Remind students that they are working for LDC and have them state the problem again. **Say:** *Today, we are going to consider the different variables we can change on the levers.* **Ask:** *How might that help us solve the problem for LDC?*
2. **Review experiments and variables.** Review the variables from the previous day. Review the requirements for a good experiment. An example of a poorly controlled experiment would be checking for bounce heights but not dropping the ball from a consistent height.

Activity
1. **Introduce the setup for the experiment.** Assign each team the variable they will be testing (fulcrum position, mass load, position of load). Each team should be sure to record what they are changing and controlling in their engineering notebooks. The experiment will use the same fulcrum set-up they used for the previous activity.
2. **Facilitate a discussion on designing experiments.** Highlight that there is a variable they will be changing, (the experimental or independent variable), and a variable they will measure in response to those changes (the response variable or dependent variable). All other variables, called control variables, should remain constant throughout the experiment. Use the experiment from lesson 2 to as an example to reinforce these ideas.

3. **Students design experiment for their specific experimental variable.** Students need to identify which variable will be changing and the range and increment of the values for this change, which response variable (which will be the effort for all experiments), and which variables are controlled and at what values they are controlled. These need to be approved before teams begin to complete experiment and collect data.
4. **Complete experiment and collect data.** Students should complete their experiment and record their data using the *3.c. Data Table for Controlled Experiment* sheet which should eventually be attached to their notebooks.
5. **Graph data.** When students are finished collecting their data they should use plot.ly to graph their points. Have students use scatter plots for their graphs. The graphs will have the experimental variable on the x-axis and the response variable (effort) on the y-axis.
6. **Use data to make prediction.** Have students consider the following:
   - If experimental variable is **mass of the load**:
     Based on your data, what force would it take to balance the load if it had a mass of ____ g?
   - If experimental variable is **position of the load**:
     Based on your data, what force would it take to balance the load if it had been placed at ____ cm from the fulcrum?
   - If experimental variable is **position of the fulcrum**:
     Based on your data, what force would it take to balance the load if the position of the fulcrum were at ____ cm from the center?

   Fill in each blank with a value for that variable that is within the range they chose for the experimental variable but not one they measured. Do not let students measure this. In their engineering notebooks, have them make a prediction and justify it using data as evidence. Verify students' predictions with a measurement. You will need to have a lever arm at the length you chose for that experiment that you can use to test their predictions.
7. **Complete Evidence-Based Reasoning (EBR) template.** Students should complete the *3.a. EBR* template. See the *3.b. EBR - Poster with Explanation* Educator Resource for instruction about what goes in each box of the EBR template. Here students will be making claims about their experimental variables and the effect on the response variable (effort).
8. **Share out the claims.** The claims should be "shared out" so that the entire class can be thinking about them during the design of their launching model. Display the list of claims for the class to see. Allow time for a class discussion regarding the claims.

Closure

1. **Tie to engineering design process.** *What step of the engineering design process do you think we worked in today?* (Learn) *Why do you think that?* (Take answers) *What do you think you learned today that might help with our design for LDC?* (Take answers)
2. **Reflection on lesson.** Have the students participate in a "thumbs up/ sideways/thumbs down" check of how well this lesson helped them understand how changing the variables in the experiment changed the effort needed to lift the load. Have students record a short reflection in their engineering notebooks about why they chose their thumb position.
3. **Collect engineering notebooks.**

Assessments

Pre-Activity Assessment

- Students state the problem in their own words. Students consider the different variables they can change on the levers and how that might help them solve the problem.

Activity Embedded Assessment

- Observe students as they run controlled experiment in order to test one variable and collect and record their data.

Post-Activity Assessment

- Students create a team claim. Then the students collect evidence about the variable they are measuring. The students will then "share out" to the entire class.
- Ask students about which step of the engineering design process they are in currently. (learn) Use the Engineering Design Process Slider as a tool for quickly assessing student understanding.

DUPLICATION MASTERS

- 3.a. Evidence Based Reasoning
- 3.c. Data Table for Controlled Experiment

EDUCATOR RESOURCES

- 3.b. Evidence-Based Reasoning - Poster with Explanation

LESSON 3

Name________________________ Date____________ Period ______

3.a. Evidence-Based Reasoning

Question Investigated through the Experiment (include variable changed)
Question:

Claim (your answer to the question)	**Data/Evidence** (Facts)

Explanation, Justification, Reasoning (Why do you think this is true?)

3.b. Evidence-Based Reasoning Poster

Poster with Explanation

Question Investigated through the Experiment (include variable changed)	
Question: the question students investigated during the experiment. For example, "What happens to the effort required to lift a load when the mass of the load is changed?"	
Claim (your answer to the question)	**Data/Evidence** (Facts)
Answer the question above. For example, "The load takes more effort to lift as the mass increases."	Observations and data that show why the student thinks his/her claim is true.
Explanation, Justification, Reasoning (Why do you think this is true?)	
Complete sentences that state why the student thinks his or her claim is true. These sentences should refer to the question, the claim, and the data/ evidence.	

LESSON 3

Name________________________________ Date___________ Period _____

3.c. Data Table for Controlled Experiment

Experimental Variable (circle one):

fulcrum position mass of load position of load

Response Variable: Effort (N)

Control Variable (circle three and provide value used):

fulcrum position __________cm

mass of load _________g

position of load ___________cm

position of effort ___________cm

Experimental Variable Values variable(units): ____________________	**Effort (N)**	**Spring Scale Weight (N)**	**Corrected Effort (N)**
		_______ N	
		_______ N	
		_______ N	
		_______ N	
		_______ N	
		_______ N	

LESSON 4 Planning and Building Launch Arm

Lesson Objectives
The students will be able to:
- Collaborate with their team to design a launcher that will launch a ping pong ball.
- Work with a team to build their launcher.

Time Required
Two 50-minute class periods

Materials
- **Per classroom:** 1 Computer with access to a projector, 1 timer, duct tape, masking tape, painter's tape, paper plates, plastic cups, paper bowls, pipe cleaners, string, straws, craft sticks-regular, craft sticks-jumbo
- **Per team:** 1 meter stick, 1 half-meter stick, 2 1-ft rulers, 3 ping pong balls, 2 ouchless hair elastics
- **Per student:** Engineering notebook*, engineering design slider*

Standards Addressed
- Next Generation Science Standards: PS2.A, MS-ETS1-4
- Common Core State Standards – Mathematics: 5.MD.B.2

Key Terms
plan, design criteria, accurate

Lesson Summary
Students will be given a 20 minute time constraint to plan their design for a launcher. The launcher will successfully launch a ping pong ball at least 2 meters, within 0.25 meters of the center of the target. This part of the engineering curriculum relies heavily on teamwork and conclusions from previous lessons on working with levers. Students will be given opportunities to write their ideas and decide on which idea will best represent the overall goal.

Background
Teacher Background
Students will need to use their previous knowledge gained from the various experiments to generate ideas for their launcher models. Students need to be reminded that engineers work with criteria and constraints, so they need to be able to finish in the time allotted.

Before the Activity
Display the graphs from the experiments to help students in making design choices. Also have some examples of materials for students to consider (paper plates, paper bowls, plastic cups, etc.). Be sure to let the students know which types of tape will be available. Also, make note of the materials that teams request so that you can have them available for the build on the second day.

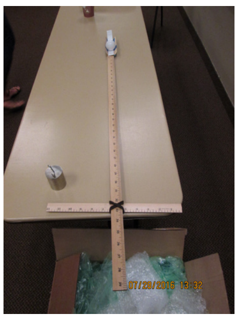
Classroom Instruction
Day 1: Planning
Introduction
1. **Review the problem.** Review the engineering problem with the class. **Say:** *LDC is hiring us to create a model that can safely detonate landmines without further injuring people or animals.* **Ask:** *What have we learned so far that might help us design this launcher model?* (Take answers.) To further this discussion, you may want to share various pictures of launchers and ask students to make observations on how they think they work. Ask the students to identify the fulcrum, load, and effort in your pictures if possible. **Say:** *Today we are going to develop ideas for our launcher models, and tomorrow we will build our launchers.*
2. **Tie to engineering design process. Ask:** *What step of the engineering design process do you think we are in today?* (Plan) Notice that this is the first time for moving into the larger "solution" section of the slider. Remind students that throughout the planning and building, they should keep notes in their notebooks as well as on any handouts given.

Activity
1. **Introduce the design challenge. Say:** *Let's think back to when we asked LDC questions about the design.* **Ask:** *What criteria and constraints did they give us?*
   - **Projectile:** ping pong ball
   - **Target:** Target will be at 2 meters from the launcher. Ping pong ball must hit within ¼ meters of the center of the target.
   - **Launcher setup** (see pictures). The launcher is made from:
     - ***Fulcrum:*** the edge of a table and one 1-ft ruler

Planning and Building Launch Arm

LESSON 4

- ***Launching arm choice:*** choose one of meter stick, half-meter stick, or 1-ft ruler
- ***Joint:*** Two ouchless hair elastics (bungee cord type) to hold fulcrum and launcher arm together.
- ***Ping pong ball holder:*** Something students design to hold the ping pong ball. *Materials for holder:* paper plates, plastic cups, paper bowls, pipe cleaners, string, straws, craft sticks-regular, craft sticks-jumbo
- ***Mass catcher:*** When students launch the ping pong balls in lesson 5, they will drop their mass onto the launching arm. The mass catcher should be a padded box. You will not need this until lesson 5.



the launcher

close-up of joint

2. **Plan their launcher model.** Have students plan their launcher models individually in their notebooks. Make sure they identify the fulcrum, load, and effort. Give them 5 minutes to plan their design individually. Then have the teams come together and develop one design to build and test. Have them record this in their notebooks as the team design.

Closure

1. **Write a memo to the client.** Have student teams write a letter to LDC describing their design from the planning step. The letter should include a picture of the launcher that identifies the fulcrum, load, lever arm, and effort and the materials needed to build their model. It should also include justifications for why they believe their design is effective (these justifications should draw on the claims the students made in the lever lessons and show how they meet the criteria and constraints set up by the client). Be sure the students use the vocabulary words: fulcrum, lever arm, load, and effort. If there is extra time, the teams may “share out” what they included in their letters to the class. You may assess the memos with the *4.a. Memo to LDC Rubric* if you would like.
2. **Collect engineering notebooks.**

Day 2: Building
Introduction

1. **Review the previous lesson.** Comment on the teams’ plans and provide reactions from the client. Hand back their memos with feedback from the client and the rubric score.
2. **Tie to the engineering challenge.** Review the engineering problem and the criteria and constraints. Tell students that they are going to build their model today, and they will test them in the next lesson.

Assessments

Pre-Activity Assessment

- Day 1: Students identify things learned to help them design a launcher model.
- Day 1 & 2: Discuss which step of the engineering design process the class is in. Use the Engineering Design Process Slider as a tool for quickly assessing student understanding.

Activity Embedded Assessment

- Day 1: Students draw the design for their launcher. Students complete the EBR graphic and questions individually. Then share their ideas with their team and collaborate to create a team launcher design plan.
- Day 2: While students are building, assess teams’ progress with the Teacher Observation Protocol: Try Lesson. Confirm that the design created on paper matches the final model.

Post-Activity Assessment

- Day 1: Students write a memo to their client about their plan.
- Day 2: Students write an updated memo to LDC. Teams must explain in writing how and why their designs meet all constraints and criteria. They should use evidence to support their claims and vocabulary words such as: fulcrum, lever arm, and load.

DUPLICATION MASTERS

- none

EDUCATOR RESOURCES

- 4.a. Memo to LDC Rubric
- 4.b. Teacher Observation Protocol: Try Lesson

Planning and Building Launch Arm

3. **Tie to the engineering design process. Ask:** *What part of the design process are we in today?* (Try) Have students review all of the things they did in each step of the design process up to this point individually, in their teams, and then report out to the whole class. You may have them do this in their notebooks if you would like to assess this.

Activity

1. **Build the launcher models.** Give students 20 minutes to construct their launcher models. While they are building, walk around and assess team progress with the *4.b. Teacher Observation Protocol: Try Lesson*. Be sure to check-in with each team.

Closure

1. **Update their memo to the client.** Have student teams update their memo to LDC explaining their design from Day 1. **Say:** *LDC wants to check on your progress today after you built your model. You and your team need to rewrite your memo explaining in writing how and why your design is going to meet the design criteria and constraints. You should use evidence to support your claims*. Again, the letter should include a picture of the launcher that identifies the fulcrum, load, lever arm, and effort and the materials needed to build their model. It should also include justifications for why they believe their design is effective (these justifications should draw on the claims the students made in the lever lessons and show how they meet the criteria and constraints set up by the client). Be sure the students use the vocabulary words: fulcrum, lever arm, load, and effort. Again, you may assess the memos with the *4.a. Memo to LDC Rubric* if you would like.
2. **Collect engineering notebooks.**

LESSON 4

Planning and Building Launch Arm

4.a. Memo to LDC Rubric

Letter should have:	3	2	1	0
Picture of your design.	Describes and draws a picture of the design using as many details as possible.	Describes and draws a picture of the design with some detail.	Describes and draws a picture with little detail.	Memo does not include a picture.
Explanation of why your model meets LDC criteria/ constraints.	Describes how each criteria/ constraint will be met.	Describes how most of the criteria/ constraints will be met.	Little or no description of the criteria/constraints that will be met.	No description of how the design will meet the criteria/ constraints.
Clear use of previous evidence.	Uses three or more places of evidence from previous investigations of levers.	Uses two pieces of evidence from previous investigations of levers.	Uses one piece of evidence from previous investigations of levers.	Memo does not provide evidence from previous investigations.
Vocabulary (fulcrum, load, lever arm, effort)	All four vocabulary words are included in the letter.	Three of the vocabulary words are included in the letter.	Two or one of the vocabulary words are included in the letter.	None of the vocabulary words are included in the letter.
Materials listed.	Students included all materials needed to build their model launcher (excluding adhesive and tools).	1 or 2 of the needed materials to build the launcher were missing (excluding adhesive and tools).	3 or 4 of the needed materials to build the launcher were missing (excluding adhesive and tools).	More than 4 of the needed materials to build the launcher were missing (excluding adhesive and tools).

LESSON 4

4.b. Teacher Observation Protocol: Try Lesson

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

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

Part 1: Behaviors

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

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

Notes:

☐ Team has made appropriate progress on their solution.

☐ Team is struggling to make their solution.

Notes:

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

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

Notes:

4.b. Teacher Observation Protocol: Try Lesson

Part 2: Question Prompts

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

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

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

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

LESSON

5 Testing Launcher

Lesson Objectives

The students will be able to:

- Work in teams to test model.
- Analyze data for the tests of the ping pong ball laucher.

Time Required

One 50-minute class period

Materials

- **Per classroom:** Space for testing launching arms, target
- **Per team:** Launching model, measuring tape in meters, targets (suggested ground level cone), ping pong balls (3), rubber bands, weight with hook (same size for each team)
- **Per student:** Engineering notebook, engineering design slider

Standards Addressed

- Next Generation Science Standards: MS-ETS1-1, MS-ETS1-4
- Common Core State Standards – Mathematics: 5.MD.A.1

Key Terms

criteria, constraint, design, precision, accuracy

Lesson Summary

Students will get the opportunity to test their launcher model. They will learn how to collect the data and measure the distance from the target. Students will analyze their test data in order to make decisions about potential changes to their laucher model.

Background

Teacher Background

The students need to test their design in order to determine consistency and effectiveness. The students will also benefit from watching other students test their models.

Before the Activity

- Map out and predetermine the area that will be used for testing. It is recommended that you stay inside because ping pong balls are highly impacted by wind. A carpeted area will help keep the balls from rolling and bouncing a significant distance from their launch position.
- It is suggested that you have designated launching zones so that teams are able to make accurate measurements. Each zone will only need one target. Mark the launch site with masking tape as the place students will put their model launchers. Make targets that are circles of radius ¼ meter with the centers marked. Place them so the centers are 2 meters from the launch site. As an option, you could have students measure out the 2 meters and mark it and then you place the target circle.

Classroom Instruction

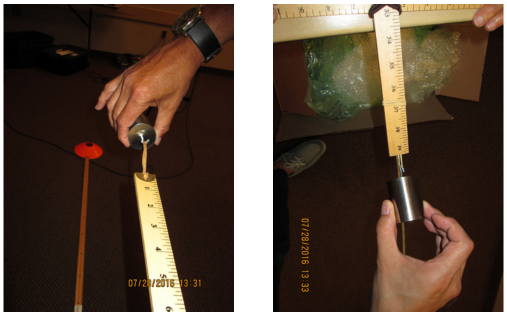
Introduction

1. **Tie lesson to engineering design.** Inform the students that they will be testing their design today. Have students move their sliders to test. Have the students write a reflection on prompt, *"Why is it important for engineers to test their designs?"* in their engineering notebooks. Review the design criteria and constraints.

Activity

1. **Demonstrate testing.** Demonstrate a launch from one of the models. Walk through the measurements (distance from target, did it land in target circle, did it launch straight to the target, to the left of the target, or to the right of the target) that will be taken and how to properly place the tape measure.
2. **Describe team roles.** The teams should be told how to rotate through the jobs so that each person completes each job at least one time. The jobs include:
   - Two people being in charge of launching.
   - One person being in charge of marking the place where the ping pong ball hits and obtains measurement from the center of the target to the hit mark.
   - One person being in charge of obtaining the launched ping pong ball
   - All students must record data individually in their notebooks for each launch.

3. **Describe the launch of the ping pong ball.** You should demonstrate a launch.In order to launch the ping pong ball:
    - Label the mass using masking tape. Write “effort” on the tape.
    - Use a rubber band to attach the mass to the lever arm on the opposite side from the ping pong (see pictures).
    - Drop the mass to launch the ball.
    - Place a box with padding under the mass for safety.



Images of masses attached to lever arm right before dropping the mass to launch the ping pong ball.

4. **Collect test data.** Have students run many tests of their launcher and collect result data in their notebooks. Students should make a data table for their tests in their notebook that have the following headings:

launch number	distance from center (m)	Did it land in the circle?	Did it land straight, left, or right of center?

5. **Analyze test data.** Have students look at their data. Were their distances from the target consistent (approximately the same distance each launch)? Do their launches go in the same direction each launch? Did their distances remain under ¼ meter?
6. **Assess students as they work.** As the students collect and analyze their test data, use the *5.a. Teacher Observation Protocol: Test Lesson* to record observations about student work.
7. **Lead a discussion about precision and accuracy in measurement.** Precision is the closeness of measurements of the launch to each other. A precise launcher will consistently launch the ping pong ball to approximately the same place. However, that place may not be close to the target. Accuracy refers to the closeness of a measurement to the target. So one launch might be accurate while another is not. An accurate launcher will provide an average of the launch measurements that is close to the target. However, this may not be precise (i.e., the launches are not close to one another). This is important for two reasons: (1) if they are getting quite precise measurements, but they are not accurate, some adjustments could be made to make it accurate too, (2) if they are getting accurate measurements but not precise, then an analysis of why the launcher does not repeat its motion should be done.
8. **Describe how design will be delivered. Say:** *You will be planning your design on the 5.b. Evidence-Based Reasoning template. This is very much like the one we did for our lever experiments.* (Show and explain

Assessments

Pre-Activity Assessment
- Discuss which step of the engineering design process the class is in. (test) Use the Engineering Design Process Slider as a tool for quickly assessing student understanding.
- Have students share the design criteria and constraints.

Activity Embedded Assessment
- Students accurately measure and record their data in their engineering notebooks.
- Walk around to each team and assess progress with the Teacher Observation Protocol: Test Lesson sheets.

Post-Activity Assessment
- Students write a memo to the client describing their outcomes. It should include if their model met the criteria and constraints, the successes and failures of the model, and how well their team worked together. Evidence should be used to back up their claims.
- Students complete engineering notebook questions.

DUPLICATION MASTERS
- 5.b. Evidence-Based Reasoning

EDUCATOR RESOURCES
- 5.a. Teacher Observation Protocol: Test Lesson
- 5.c. Evidence-Based Reasoning Poster
- 5.d. Engineering Notebook Questions

5.c. Evidence-Based Reasoning Poster.) **Say:** *On your design plan, identify your fulcrum, load, and effort. You have 20 minutes to plan your design (5 minutes as individuals, 15 minutes in team).* At the end of the 20 minutes, teams need to turn in their design plan including the materials they will need.

Closure

1. **Answer testing notebook prompts individually.** Have students individually answer the questions from *5.d. Engineering Notebook Questions* in their engineering notebooks. You can either post these so students can see them or copy 5.d. and have students attach them in their notebooks. If you have students fill in 5.d., then you can have them individually fill out each question under the “My response:” space. Then, based on their discussion with their team, write their revised answer in the “Team response:” space. You may want students to use a different color writing utensil to distinguish their individual answer and how it changed after talking with their teammates.
2. **Answer notebook prompts in teams and discuss.** Have students share and discuss their answers in their teams. They should use a different colored utensil to write their team’s answer in their engineering notebook. Team ideas can be “shared out” to the entire class.
3. **Collect engineering notebooks from students**.

Testing Launcher

LESSON 5

5.a. Teacher Observation Protocol: Test Lesson

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

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

Part 1: Behaviors
Testing

☐ All team members are on-task to test solution.

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

Notes:

☐ Team has made appropriate progress on testing and analysis.

☐ Team is struggling to test or analyze their solution.

Notes:

☐ Team has identified how to improve solution.

☐ Team is struggling to consider improved performance.

Notes:

5.a. Teacher Observation Protocol: Test Lesson

Part 2: Question Prompts

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

4. What did you find out from testing?

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

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

LESSON 5

Name________________________________ Date____________ Period _____

5.b. Evidence-Based Reasoning

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

Problem: ____

____

Criteria: ____

Constraints: ____

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

____

____

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

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

____

5.c. Evidence-Based Reasoning Poster

Poster with Explanation

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

Problem: the engineering problem the client asked you to solve

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

Constraints: things that limit design possibilities

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

Ways to make a complex problem simpler

Plan (Design Idea)	**Data/Evidence** (Facts)
• Description of the design • Drawings of the design, different views • Dimensions (sizes) • Label materials in design (show where they are used) • Interesting features	Observations and data that show why you think your design will work Examples: • Data from previous launches • Information gathered during the lever experiments

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

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

5.d. Engineering Notebook Questions

Testing Results Questions

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. **What have you learned about the performance of your solution from your test results?**
   My response:

   Team response:

2. **What changes will you make to your solution based on the results of your tests? Explain why you want to make those changes.**
   My response:

   Team response:

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

   Team response:

5.d. Engineering Notebook Questions

4. **In what ways does your solution meet the criteria and constraints of the problem?**
   My response:

   Team response:

5. **In what ways does your solution not yet meet the criteria and constraints of the problem?**
   My response:

   Team response:

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

   Team response:

LESSON 6

Redesign and Testing with New Challenge

Lesson Objectives

The students will be able to:

- Work in cooperative teams to redesign a lever arm in order to meet new criteria from LDC by using previous designs and information gained

Time Required

Two 50-minute class periods

Materials

- **Per classroom:** 1 Computer with access to a projector., 1 timer, duct tape, masking tape, painter's tape, paper plates, plastic cups, paper bowls, pipe cleaners, string, straws, craft sticks-regular, craft sticks-jumbo
- **Per team:** 1 fulcrum, 1 meter stick, 1 half-meter stick, 1 1 ft ruler, 3 ping pong balls
- **Per student:** Engineering notebook, engineering design slider

Standards Addressed

- Next Generation Science Standards: MS-ETS1-2, MS-ETS1-3
- Common Core State Standards – Mathematics: 5.MD.A.1

Key Terms

none

Lesson Summary

In the redesign challenge, each team will get one additional constraint or criteria added to their requirements. In order to be successful, they will have to accomplish one of the following:

- Launch 1 meter to within 10 centimeters of the center of the target.
- Launch 1.5 meters to within 15 centimeters of the center of the target.
- Launch 2 meters to within 20 centimeters of the center of the target.

Students will be required to work cooperatively in teams to plan out the redesign using evidence and data from previous investigations and from the results of the first test. Be sure to give plenty of time to build and test the new launcher. After the test, the students will evaluate the success of their model.

Before the Activity

Each team should be assigned a specific part of the new criteria to test. Based on the previous work, assign teams so they are challenged and will need to push their thinking. For example, if a team was able to hit the target with their first design assign them to gain greater accuracy by having to hit closer to the target.

Classroom Instruction

Day 1 - Introduction

1. **Review the engineering design process with students. Ask:** *What steps did you take today to get to where you are now with your launcher model design?* Help students identify the steps in the design process, how they have progressed, and where they are now. Have them record in their notebooks.
2. **Introduce additional criteria/constrains for engineering challenge. Say:** *LDC has read over the memo that was submitted to evaluate the initial design and test. They are interested in seeing if we can make our designs even better. They have asked us to each take on one additional constraint as we do a redesign of our launcher models. These are: (1) launch 1 meter to within 10 centimeters of the center of the target, (2) launch 1.5 meters to within 15 centimeters of the center of the target, or (3) launch 2 meters to within 20 centimeters of the center of the target. You will each be assigned one of these conditions.*
3. **Tie to engineering design process. Ask**: *Where are we now in the engineering design process?* Discuss which step of the engineering design process students are in. They are in the "Solution" section of the Engineering Design Process. They have returned to the "plan" step.

Activity - Redesign and Build

1. **Assign teams to the new constraints.** Students are given new design constraints for design challenge 2. Assign each team one of the three new constraints.
    - Using a ping pong ball, launch 1 m within 10 cm of center.
    - Using a ping pong ball, launch 1.5 m within 15 cm of center.
    - Using a ping pong ball, launch 2 m within 20 cm of center.
2. **Plan the redesign.** Students will be given 15 minutes for planning with team for design challenge 2. Have them plan with the *6.a. Evidence-Based Reasoning* sheet.

Redesign and Testing with New Challenge

3. **Build redesigned launcher model.** Students should then build their redesigned launcher arm. As students are building, assess their progress using *6.b. Teacher Observation Protocol: Try Lesson* sheet.

Closure

1. **Reflect on teamwork in notebooks. Prompt**: *How well did your team work together on your redesign of the launcher? Give 3 specific details about how you cooperated.*

Day 2 - Introduction

1. **Remind students of the importance of testing their prototypes.** Tell students that they will be testing their redesigned launcher models and that they should keep careful notes in their notebooks throughout the day. Have them identify the criteria and constraints they are testing.

Activity - Retest

1. **Remind students of how to test.** You may want to demonstrate a launch from one of the models again. Walk through the measurements (distance from target, did it land in target circle, did it launch straight to the target, to the left of the target, or to the right of the target) that will be taken and how to properly place the tape measure. Remind them of their new constraints.
   Note: You may also want to make appropriate sized targets for each constraint and set up the test sites before class.
2. **Describe team roles.** The teams should be told how to rotate through the jobs so that each person completes each job at least one time. The jobs include: launcher, marker of the place where the ping pong ball lands, measurer (from the center of the target to the landing site), and retriever of the launched ping pong ball.
   - All students must record data individually in their notebooks for each launch.
3. **Collect test data.** Have students run many tests of their launcher and collect result data in their notebooks. Students should make a data table for their tests in their notebook that have the following headings:

launch number	distance from center (m)	Did it land in the circle?	Did it land straight, left, or right of center?

4. **Analyze test data.** Have students look at their data. Were their distances from the target consistent (approximately the same distance each launch)? Do their launches go in the same direction each launch? Did their distances remain within their constraints?
5. **Assess students as they work.** As students are testing, assess their progress using *6.c. Teacher Observation Protocol: Retest Lesson* sheets.

Closure

1. **Reflect in notebooks.** The students should respond to the prompt, *How did the change in constraints impact your ability to be successful?* in their engineering notebooks.
2. **Collect engineering notebooks.**

Assessments

Day 1

Pre-Activity Assessment

- Notebook reflection on student path through the engineering design process and current step. Use the Engineering Design Process Slider as a tool for quickly assessing student understanding.

Activity Embedded Assessment

- As students redesign, assess their progress through the *Teacher Observation Protocol: Try Lesson* sheets.

Post-Activity Assessment

- Notebook prompt on teamwork.

Day 2

Pre-Activity Assessment

- Have students identify the criteria they will be testing through questioning.

Activity Embedded Assessment

- As students retest, assess their progress through the *Teacher Observation Protocol: Test Lesson* sheets.
- Teacher should monitor testing for accuracy of measurement and recording.

Post-Activity Assessment

- Notebook prompt - **Ask:** *How did the change in constraints impact your ability to be successful?*

DUPLICATION MASTERS

- 6.a. Evidence-Based Reasoning

EDUCATOR RESOURCES

- 6.b. Teacher Observation Protocol: Try Lesson
- 6.c. Teacher Observation Protocol: Retest Lesson

LESSON 6

Name________________________ Date____________ Period ______

6.a. Evidence-Based Reasoning

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

Problem: ____

____

Criteria: ____

Constraints: ____

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

____

____

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

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

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6.b. Teacher Observation Protocol: Try Lesson

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

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

Part 1: Behaviors

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

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

Notes:

☐ Team has made appropriate progress on their solution.

☐ Team is struggling to make their solution.

Notes:

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

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

Notes:

6.b. Teacher Observation Protocol: Try Lesson

Part 2: Question Prompts

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

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

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

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

6.c. Teacher Observation Protocol: Retest Lesson

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

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

Part 1: Behaviors

Testing Improved Solution

☐ All team members are on-task to retest solution.

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

Notes:

☐ Team has attempted to improve performance of solution.

☐ Unclear what improvements team made.

Notes:

Name________________________________ Date___________ Period _____

6.c. Teacher Observation Protocol: Retest Lesson

Part 2: Question Prompts

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

7. What did you find out from testing?

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

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

LESSON

7 Communication to LDC

Lesson Objectives

The students will be able to:

- Work in cooperative teams to communicate and justify their overall design to LDC.

Time Required

One 50-minute class period

Materials

- **Per classroom:** none
- **Per team:** Data from previous lessons, laptop or iPad to type memo* (not required), poster paper* (not required)
- **Per student:** Engineering notebooks*

Standards Addressed

- Next Generation Science Standards: MS-ETS1-3
- Common Core State Standards – Mathematics: 6.SP.B.5 (Note that this is a standard that the students will not necessarily have mastered.)

Key Terms

explanation, weakness, justification

Lesson Summary

Students will work in teams to communicate with LDC the overall problem, including a claim on why their design is successful, evidence to support the claim, an explanation for why their design should be selected, and an address of any weaknesses in their design. Students should use evidence to support all claims. Students will be allowed to choose from a variety of methods that engineers use to communicate to their clients (letter, presentation, poster, etc.).

Background

Teacher Background

To finish out the unit, students will choose a way to clearly communicate their findings to LDC. It is important for students to continue working on the understanding of how engineers work with others and their need to explain their progress and ideas to their client. Allow freedom of communication style to help student engagement by either providing a list or having the class produce a list of possibilities. Students are given a deadline based on your judgment. If you would like, the students may present their communication to the class.

Before the Activity

It may be helpful to generate your own list of ways you want students to present their information. Be sure to clearly review what components they need along with how they will be critiqued.

Classroom Instruction

Introduction

1. **Tie to engineering challenge. Say:** *What have we done for LDC so far?* (Take answers). **Ask:** *Where do you think we are now in the engineering design process?* (Decide and communicate)
2. **Generate ideas for communication strategies.** In student teams, have them generate ideas for how they, as engineers, might communicate their final designs to the client. Be sure to include the idea that the communication choice must include justification for design choices. As a class decide on how you will communicate your designs to the client.

Activity

1. **Develop guidelines as a class for final communication. Say:** *Now that we have decided to use [insert type of communication strategy] to communicate to LDC, we need to make sure we give them good information about our designs.* **Ask:** *What are the criteria that LDC wants you to meet for your final design? What do you think needs to be included in the communication to the client?*

    Note: Let students come up with as much as they can about what should be in their communication. Make sure the list includes a picture or drawing of their model launcher with a description, a claim on why their design is successful, evidence to support the claim, an explanation for why their design should be selected, and statements of any weaknesses in their design.
2. **Give directions for final communication. Say:** *This will be the justification for your final design to your client. There will be a time constraint because LDC needs to have the information by the end of class today. Be sure to*

meet all criteria we developed as a class. Have students fill out the *7.a. Evidence-Based Reasoning* to help them organize their communication. You can assess this using the *7.b. Final Communication to LDC Rubric* or use it as formative assessment so you can help students communicate more clearly to the client.

3. **Turn in or present communication to the client.** If students choose presentations, you will need to provide time to do this. You can assess the communication with the *7.b. Final Communication to LDC Rubric*.

    Note: You may need to add to this rubric if your students added additional items to the requirements for the communication.

Closure

1. **Answer unit reflection notebook prompts individually.** Have students individually answer the questions from *7.c. Engineering Notebook Questions* in their engineering notebooks. You can either post these so students can see them or copy them and have students attach them in their notebooks.
2. **Answer notebook prompts in teams and discuss.** Have students share and discuss their answers in their teams. They should use a different colored utensil to write their team's answer in their engineering notebook. Team ideas can be "shared out" to the entire class.

Assessments

Pre-Activity Assessment

- Discuss which step of the engineering design process the class is in. (decide and communicate) Use the Engineering Design Process Slider as a tool for quickly assessing student understanding.
- Students generate ideas for how they should communicate to their client.

Activity Embedded Assessment

- Students fill out an Evidence-Based Reasoning Solution Graphic
- Use of the Final Communication to LDC Rubric to assess communication to the client.

Post-Activity Assessment

- Check students' written reflections of the entire unit: how their thinking about the problem and how to design a solution has changed during the design process, as well as how they think engineers solve problems.

DUPLICATION MASTERS

- 7.a. Evidence-Based Reasoning
- 7.b. Final Communication to LDC Rubric

EDUCATOR RESOURCES

- 7.c. Engineering Notebook Questions

LESSON 7

Name________________________________ Date____________ Period _____

7.a. Evidence-Based Reasoning

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

Problem: ____

____

Criteria: ____

Constraints: ____

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

____

____

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

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

____

____

____

____

____

____

____

LESSON 7

Name________________________________ Date____________ Period ______

7.b. Final Communication to LDC Rubric

Communication should have:	3	2	1	0
Description of your design. Explanation of how your model meets LDC criteria.	Describes and draws a picture of the design labeling all parts. Explanation of all materials used.	Describes and draws a picture of the design labeling some parts. Explanation of some materials used.	Describes and draws a picture labeling one part. Explanation of a few materials used, some materials missing.	If any of the following are true: • No picture • No labels • No materials
Explanation of the model to LDC.	Explains both how to hit 2 m target and how to adjust the distance. Explanations are scientifically accurate.	Explains how to hit 2 m target and/ or how to adjust the distance. Explanation is mostly scientifically accurate.	Explains only one of how to hit 2 m target or how to adjust the difference and/ or explanation is partially not scientifically accurate.	Explanation is mostly not scientifically accurate.
Clear use of previous evidence.	Uses three or more pieces of evidence from previous investigations or prior knowledge.	Uses two pieces of evidence from previous investigations or prior knowledge.	Uses one piece of evidence from previous investigations or prior knowledge.	No use of evidence from previous investigations or prior knowledge.
Vocabulary (fulcrum, load, lever arm, effort)	All four vocabulary words are included in the communication.	Three of the vocabulary words are included in the communication.	Two of the vocabulary words are included in the communication.	One or zero of the vocabulary words are included in the communication.

7.c. Engineering Notebook Questions

Unit Engineering Reflection Questions

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

   Team response:

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

   Team response:

3. How do engineers solve problems?
   My response:

   Team response:

Notebook Prompts and Titles

Teacher Directions:

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

Prompt title:

Question to answer

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

Problem Scoping Lessons - Define and Learn

Section 1:

Engineers:

What do engineers do?

Solve Problems:

How do engineers solve problems?

Section 2:

Questions for client:

What questions do you want to ask to the client?

Section 3:

Client:

Who is the client?

Problem:

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

Why it is important:

Why is the problem important to solve?

End-users:

Who are the end-users?

Criteria:

What will make the solution effective (criteria)?

Notebook Prompts and Titles

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

What we need to learn:
Think about the problem of active landmines and accidental detonation. In terms of launching an item to detonate the landmines, what do you need to learn in order to create a successful launch?

Generate Ideas/Plan Lessons

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

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

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

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

Test Solution Idea(s) Lessons

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

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

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

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

Notebook Prompts and Titles

Section 2:

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

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

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

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

Decide/Final Solution Lessons

Section 1:

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

Section 2:

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

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

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

