EngrTEAMS

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

Planet Andoddin

Grades 4-5

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

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About EngrTEAMS

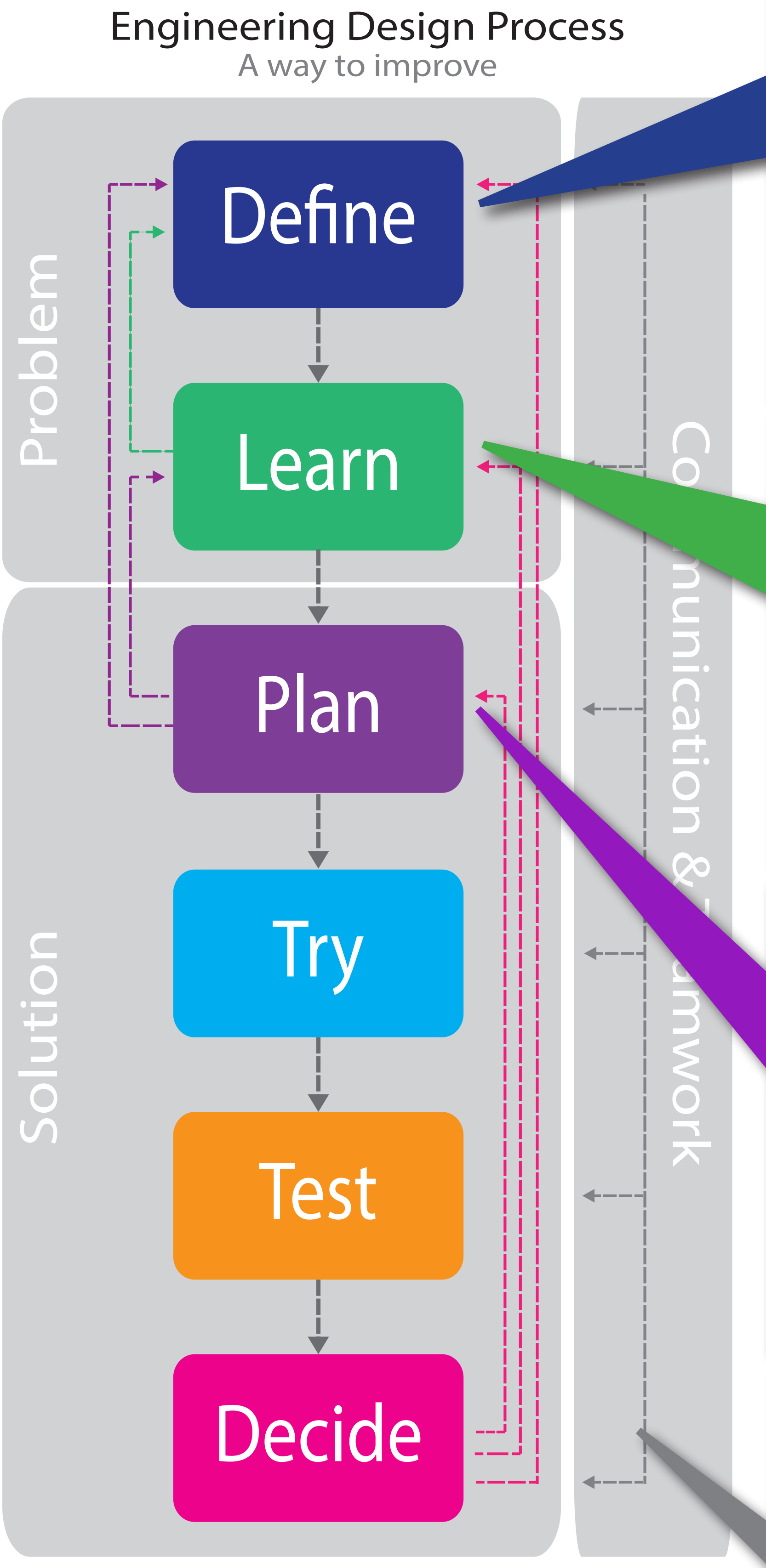
Purpose

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

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

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

Overview: Engineering Design Process



DEFINE THE PROBLEM

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

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

LEARN ABOUT THE PROBLEM

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

PLAN A SOLUTION

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

COMMUNICATION

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

Overview: Engineering Design Process

TRY A SOLUTION

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

TEST A SOLUTION

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

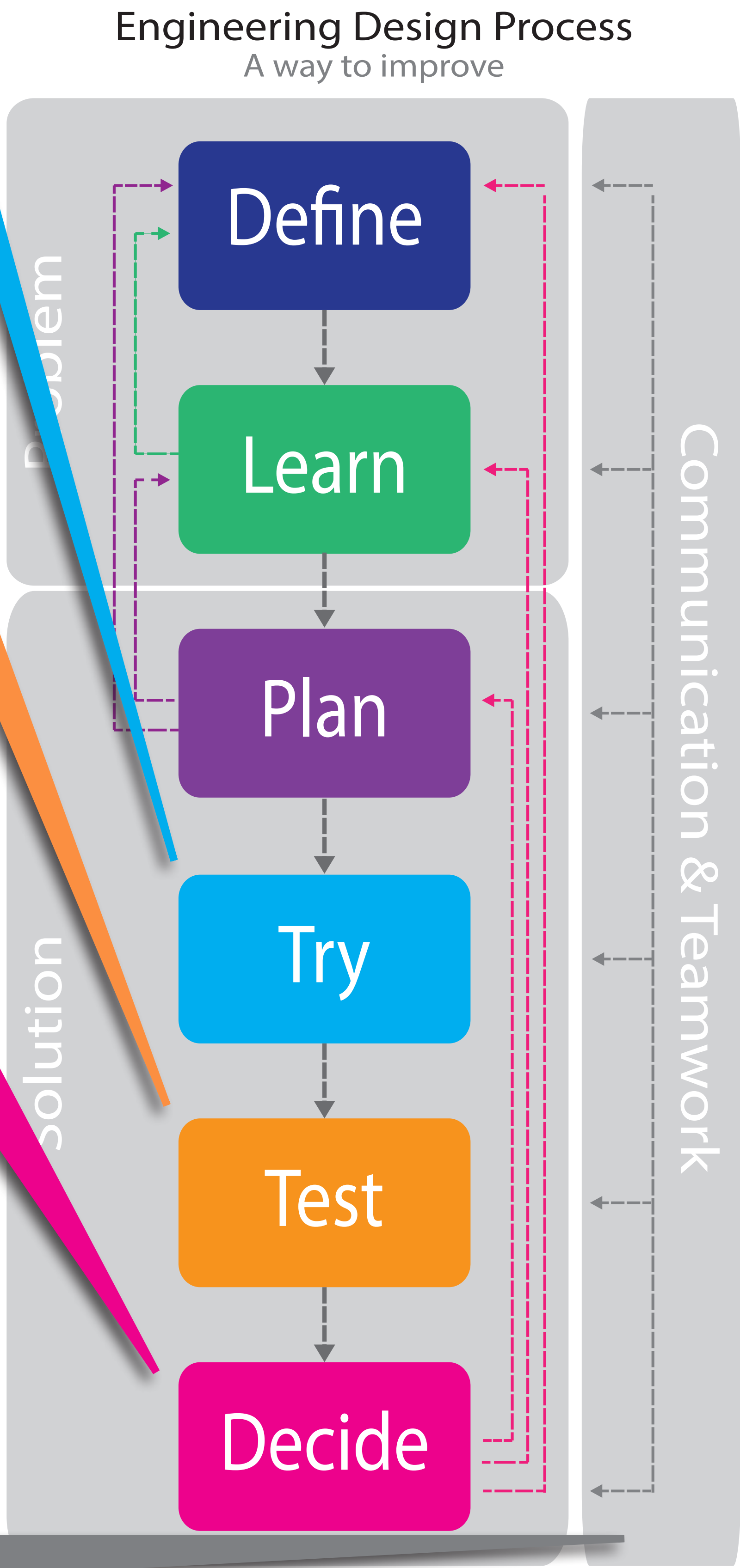
DECIDE IF THE SOLUTION IS GOOD ENOUGH

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

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

TEAMWORK

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



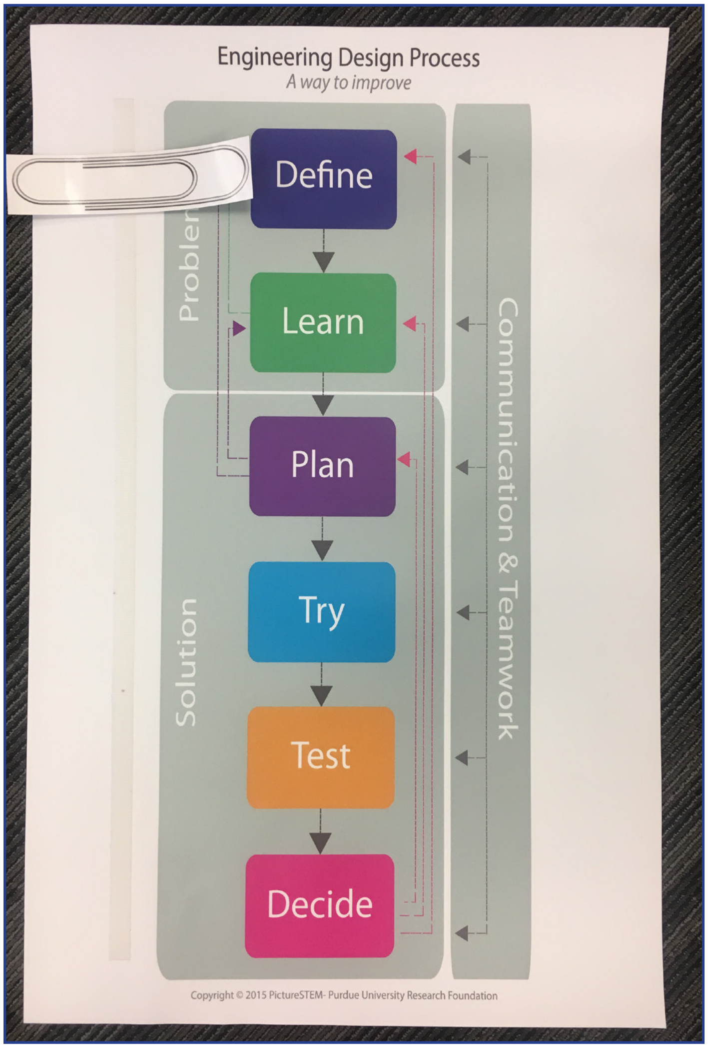
Overview: How to make EDP sliders

HOW TO CREATE THE POSTER

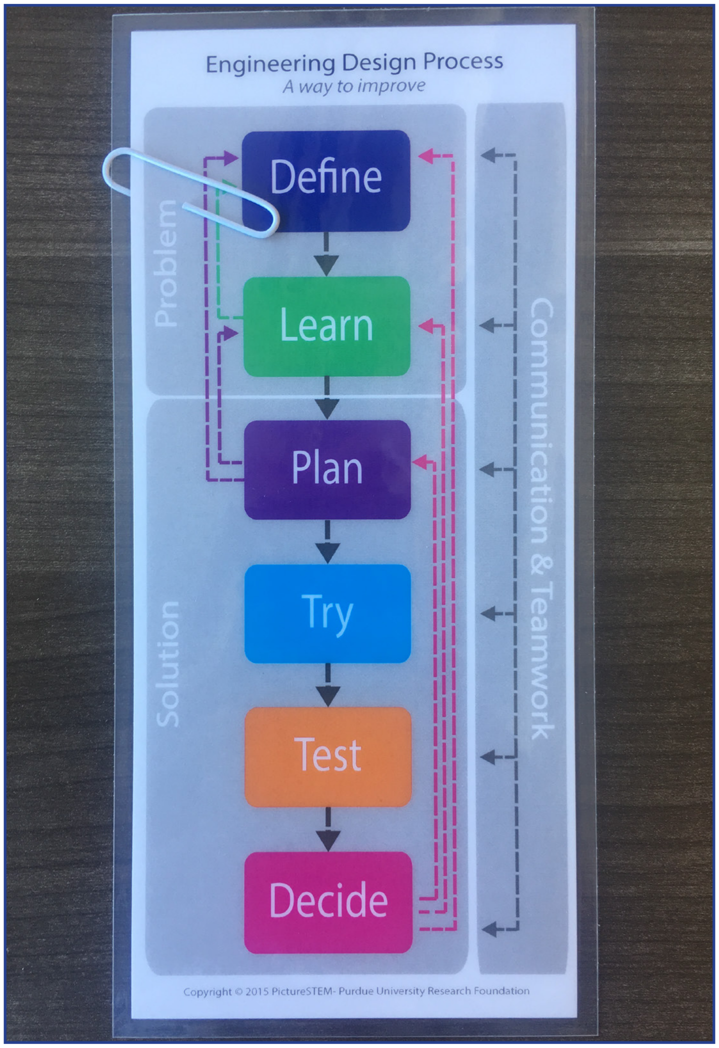
1. Download the high-quality PictureSTEM Slider Poster and the paper clip images from PictureSTEM.org.
2. Print the poster and the paper clip on poster-sized paper and cut to size. High-gloss or semi-gloss paper is the best choice.
3. Use self-sticking Velcro on the back of the paper clip and down the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

HOW TO CREATE INDIVIDUAL SLIDERS

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

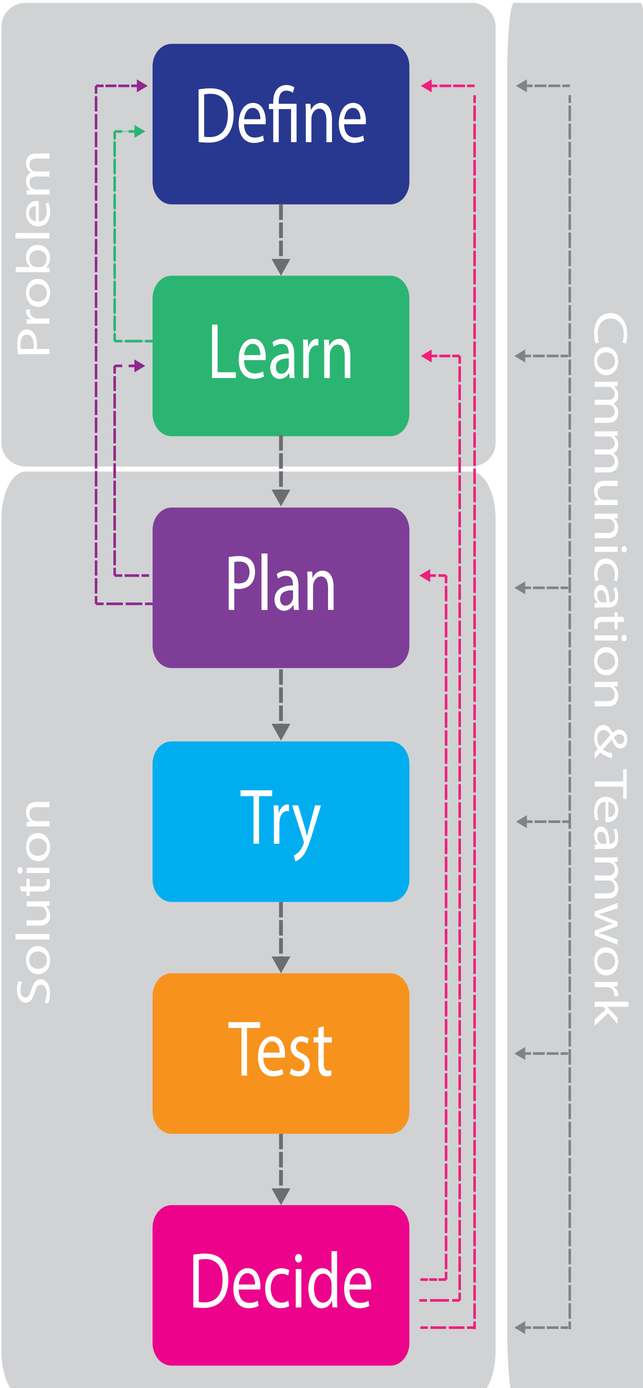


Poster

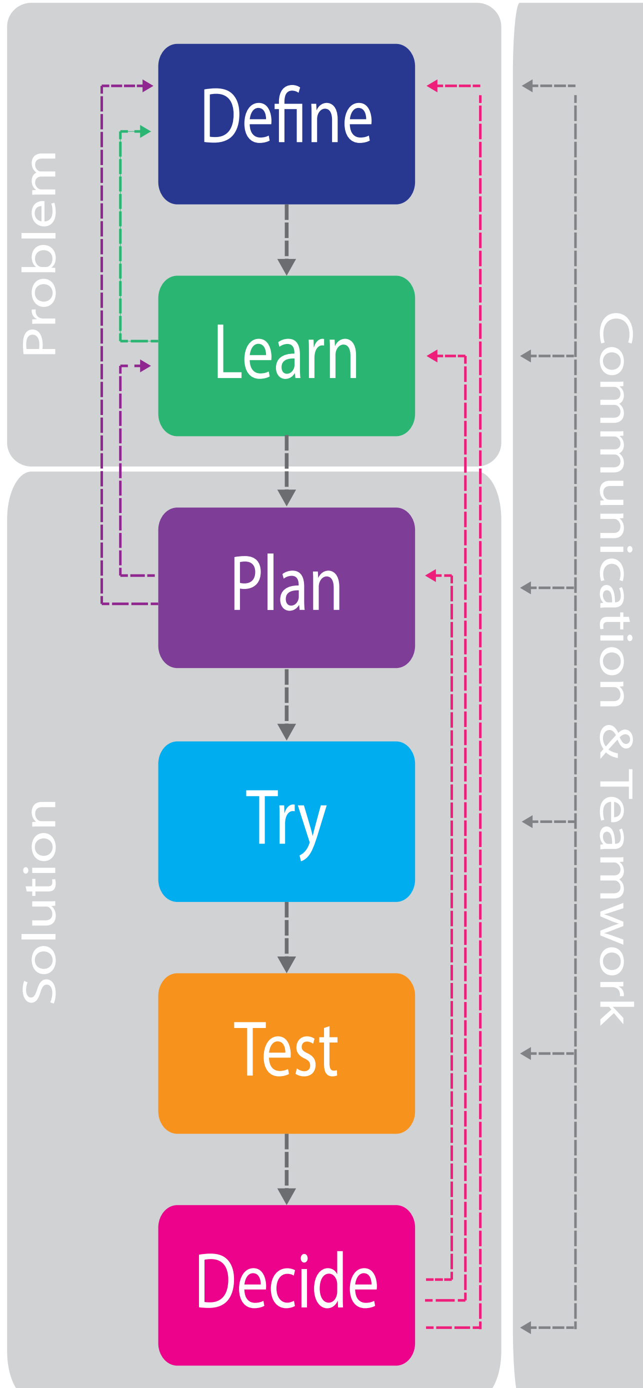


Individual slider

Engineering Design Process
A way to improve



Engineering Design Process
A way to improve



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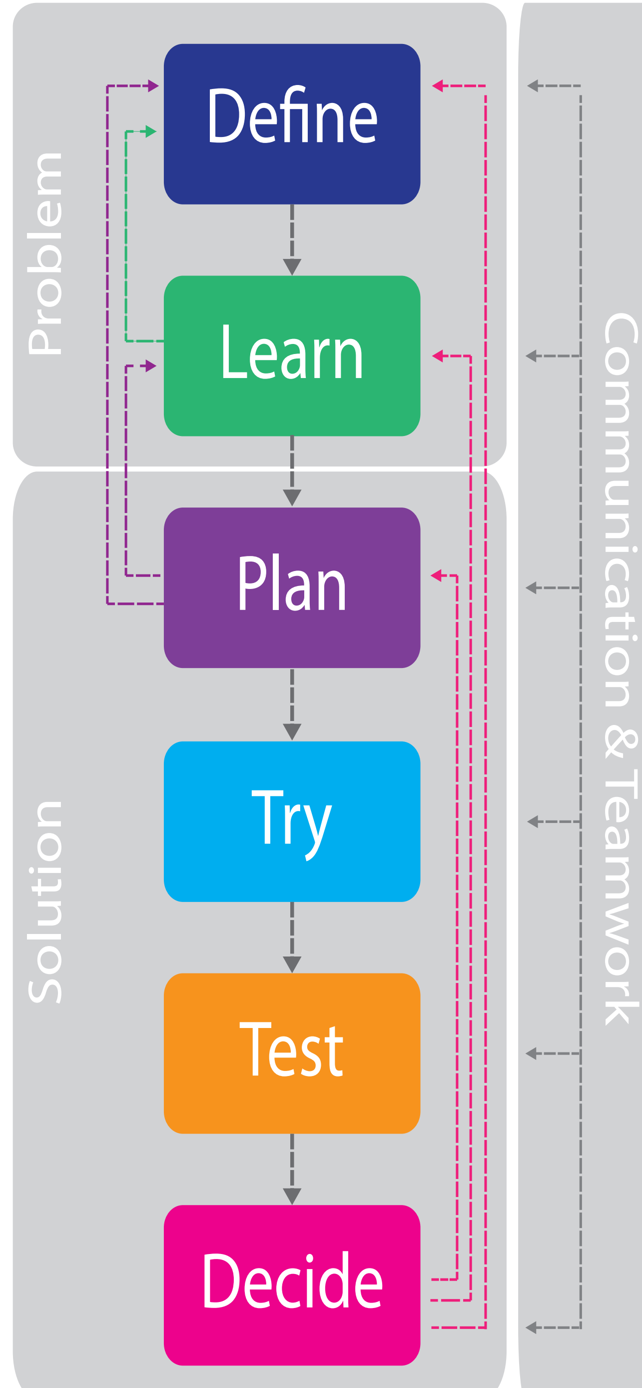
Engineering Design Process
A way to improve



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Overview: Unit Description

Grade Levels:

4-5

Approximate Time Needed to Complete Unit:

Eleven-thirteen 50-minute class periods

Unit Summary

Students are introduced to their client, Micah Bergmann of New World Resource Management, a corporation that has discovered resources on an exoplanet, Andoddin. Students are tasked with a two-part engineering design challenge. First, they must analyze data from four different resource extraction sites on the exoplanet in order to choose where to extract trees, iron ore, and gravel. Second, they design tools to extract those resources. Before designing solutions, students learn about renewable and nonrenewable resources and the environmental impact of extracting resources. They then choose an extraction site and plan, try (build), test, and decide about (evaluate) a resource extraction tool twice, once as an initial design and once in redesign. Finally, student teams write letters and/or create posters for their client, describing their solutions and justifying them with evidence.

Science Connections	Technology & Engineering Connections	Mathematics Connections
renewable and nonrenewable resources, environmental impact	complete full engineering design process, including: problem scoping (define and learn about the problem), solution generation (plan, try/build, test, decide about a solution), redesign, and communication of final design to client	perform operations with decimals in real-world cost problems, measure areas by counting unit squares, convert improper fractions to mixed numbers

Unit Standards

Next Generation Science Standards

- **4-ESS3-1:** Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.
- ***MS-ESS3-1:** Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes. **While this unit does not fully cover the disciplinary core ideas of this standard, it does address key ideas that are foundational to this standard: that resources are limited, often nonrenewable, and that these resources are not evenly distributed on a planet.*
- **3-5-ETS1-1:** Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- **3-5-ETS1-2:** Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- **3-5-ETS1-3:** Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Overview: Unit Description

Common Core State Standards - Mathematics

- **4.MD.A.2:** Use the four operations to solve word problems involving distances, intervals of time, liquid volumes, masses of objects, and money, including problems involving simple fractions or decimals, and problems that require expressing measurements given in a larger unit in terms of a smaller unit. Represent measurement quantities using diagrams such as number line diagrams that feature a measurement scale.
- **3.MD.C.6:** Measure areas by counting unit squares (square cm, square m, square in, square ft, and improvised units).
- **3.MC.C.7.D:** Recognize area as additive. Find areas of rectilinear figures by decomposing them into non-overlapping rectangles and adding the areas of the nonoverlapping parts, applying this technique to solve real world problems.
- **3.NF.A.3.B:** Recognize and generate simple equivalent fractions, e.g., 1/2 = 2/4, 4/6 = 2/3. Explain why the fractions are equivalent, e.g., by using a visual fraction model.
- **4.NF.B.3.B:** Decompose a fraction into a sum of fractions with the same denominator in more than one way, recording each decomposition by an equation. Justify decompositions, e.g., by using a visual fraction model. *Examples: 3/8 = 1/8 + 1/8 + 1/8 ; 3/8 = 1/8 + 2/8 ; 2 1/8 = 1 + 1 + 1/8 = 8/8 + 8/8 + 1/8.*

Unit Assessment Summary

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

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

Overview: Lesson Summaries

Lesson 1: Define the Engineering Problem

Students learn about the organized system of problem-solving steps called the engineering design process. By reading a letter from the client and asking the client additional questions, students learn about the specifics of their engineering problem, which is to create tools to extract resources from Planet Andoddin and select a site for extracting resources on the planet upon arrival. Using this information, students define the engineering problem, which includes identifying the problem and why it's important, client, end-users, criteria, constraints, and what else they need to learn in order to design effective solutions.

Lesson 2: Renewable and Nonrenewable Resources

Students read and analyze an article in order to learn about natural resources and renewable and nonrenewable resources. They then apply that knowledge by identifying renewable and nonrenewable material and energy resources.

Lesson 3: Resource Extraction: Cookie Mining

Students complete a cookie mining activity to learn about the environmental impact of extracting resources. They purchase cookies and mining tools, then extract as many chocolate and rainbow chips from the cookies as they can in a given time. Students calculate the cost of the cookies and tools, as well as the profit earned depending on how many chips they mine. The activity teaches students about the environmental impact of mining and explains the importance of extracting resources using low impact methods.

Lesson 4: Site Selection & Tool Design Idea Generation

Student teams are each assigned one resource (i.e., wood, gravel rocks, iron ore) to focus on during engineering solution generation. Teams then analyze cross-sectional maps of four different sites on Andoddin that show the distribution of resources in order to choose which site would be best to extract their assigned resource from. After learning about the materials available for the resource extraction tool design and their cost, students individually generate multiple possible design solutions.

Lesson 5: Tool Design Selection & Evidence-Based Reasoning

Students review what information they have learned about the engineering problem and use it to continue solution generation. They use a list of materials and their cost, as well as what they have learned about natural resources, resource extraction, and environmental impact, to design a tool for mining their team's assigned resource from their chosen site. In the previous lesson, students generated multiple possible design solutions individually. In this lesson, they meet as a team and use the ideas generated individually to determine one design solution that will be implemented and tested. Students use evidence-based reasoning to justify their proposed design solution.

Overview: Lesson Summaries

Lesson 6: Try a Solution

Students implement their planned design and create a prototype resource extraction tool. Before students can obtain materials, they submit two items to the teacher for approval: a *5.d. Evidence-Based Reasoning* worksheet, explaining the team's chosen design, and a *4.i. Materials Cost Sheet* with materials chosen and cost amounts calculated. Once checked, the teacher distributes materials and offers guidance to teams if they seem to have forgotten materials.

Lesson 7: Test a Solution

Students test their resource extraction tool prototype by using it to extract their assigned resource from the Andoddin site they chose in Lesson 4. After 10 minutes of extraction, they measure how many resources their tool prototype has extracted. Also, they use a grid to measure approximately how much environmental impact their tool prototype had on the surface of Andoddin. The focus of this testing lesson is to gather data about the performance of the tool prototype.

Lesson 8: Decide About a Solution

Student teams share their resource extraction tool prototype and results with other teams assigned to the same resource. They analyze their prototype's performance data in comparison with other teams in order to determine why some designs work better than others. Students decide how well their design met each of the criteria and then begin thinking about redesign.

Lesson 9: Redesign

Based on the discussion and analysis of the initial design test results, students work to improve their resource extraction tool. Students redesign, rebuild, retest and reevaluate the performance of a tool prototype. Students compare and contrast their results with the results of their initial design and decide on which design to suggest to the client as the solution to the engineering problem.

Lesson 10: Communicate to the Client

In this lesson, students write a letter to or create a poster for the client, Micah Bergmann of New World Resource Management, about their design. The letter or poster needs to explain the design with text and drawings, and justify the design with evidence and explanations.

Overview: Unit Overview

Lesson	Time Needed	Objectives The student will be able to:
1: Define the Engineering Problem	one-two 50-minute class period(s)	• describe important features of an engineering design process. • define an engineering problem from the perspective of stakeholders. • generate and then refine a description of the problem based on new information. • engage in problem scoping (i.e., define the problem and needs, and then identify the knowledge, criteria, and constraints required for a desirable solution).
2: Renewable and Nonrenewable Resources	one 50-minute class period	• define natural resources. • describe the difference between renewable and nonrenewable natural resources. • identify whether natural resources are renewable or nonrenewable.
3: Resource Extraction: Cookie Mining	one 50-minute class period	• describe mining as the process of extracting resources from the ground. • explain environmental impact and how mining decisions affect the environment. • add, subtract, and multiply costs with decimals to calculate profit.
4: Site Selection & Tool Design Idea Generation	one 50-minute class period	• use cross-sectional maps to identify where their assigned resource is located at each site. • justify their decision about which site they will extract their resource from. • use evidence from problem scoping to generate multiple initial ideas for a design solution. • add and multiply decimals to calculate the cost of the design.
5: Tool Design Selection & Evidence-Based Reasoning	one 50-minute class period	• systematically evaluate various solutions based on the problem to narrow to one design solution. • justify why their proposed design solution is appropriate based on the application of core science/mathematics concepts, and information obtained in problem scoping. • add and multiply decimals to calculate the cost of the design, keeping the cost under $12.00.

Overview: Unit Overview

Materials	Duplication Masters & Educator Resources
• **Per classroom:** Engineering Design Process poster, poster size sticky-note paper labeled "Questions for Client", markers • **Per student:** (2) different colors or types of writing utensils, engineering notebook, Engineering Design Process slider	**DUPLICATION MASTERS** • 1.a. What Do You Know About Engineers? • 1.b. NWRM Client Letter • 1.c. Questions for the Client • 1.d. Define the Problem **EDUCATOR RESOURCES** • 1.e. Questions for the Client and Define the Problem Rubric • 1.f. Define the Problem Answer Key
• **Per classroom:** Engineering Design Process poster • **Per team: (optional)** mini white board, dry erase marker, sheets of paper, marker • **Per student:** (2) different colors or types of writing utensils, engineering notebook, Engineering Design Process slider	**DUPLICATION MASTERS** • 2.b. Natural Resources Vocabulary • 2.d. Identify Renewable and Nonrenewable Resources • 2.f. Natural Resources Exit Slip **EDUCATOR RESOURCES** • **(Optional)** 2.a. NWRM Lesson 2 Memo • 2.c. Natural Resources Vocabulary Answer Key • 2.e. Identify Renewable and Nonrenewable Resources Answer Key • 2.g. Natural Resources Exit Slip Answer Key
• **Per classroom:** Engineering Design Process poster, timer or clock, paper clips, toothpicks, plastic spoons, craft sticks • **Per student:** (1) rainbow chip/chocolate chip cookie, (1) paper plate, (2) different colors or types of writing utensils, engineering notebook, Engineering Design Process slider	**DUPLICATION MASTERS** • 3.b. Cookie Mining Cost Sheet • 3.c. Cookie Mining Questions **EDUCATOR RESOURCES** • **(Optional)** 3.a. NWRM Lesson 3 Memo
• **Per classroom:** Engineering Design Process poster, toothpicks, craft sticks, paper clips, pipe cleaners, bamboo skewers, 3 oz. paper cups, mesh screens (2.5"x2.5"), magnets, 4"x6" notecards, rubber bands, string, masking tape, one prepared site, which includes: (1) medium plastic tub, approx. 10 lbs. sand, large gravel (~3/4"), steel washers, trees (each is one 1" pom-pom, one 2"x¼" dowel rod, one 1 oz. plastic cup), glue gun and glue, aquarium rocks • **Per student:** (2) different colors or types of writing utensils, engineering notebook, Engineering Design Process slider	**DUPLICATION MASTERS** • 4.c. Andoddin Site 1 Map • 4.d. Andoddin Site 2 Map • 4.e. Andoddin Site 3 Map • 4.f. Andoddin Site 4 Map • 4.g. Extraction Site Choice • 4.h. NWRM Additional Design Information • 4.i. Materials Cost Sheet • 4.j. Design Ideas – Individual Plan **EDUCATOR RESOURCES** • 4.a. Andoddin Site Instructions • **(Optional)** 4.b. NWRM Lesson 4 Memo
• **Per classroom:** Engineering Design Process poster, toothpicks, craft sticks, paper clips, pipe cleaners, bamboo skewers, 3 oz. paper cups, mesh screens (2.5"x2.5"), magnets, 4"x6" notecards, rubber bands, string, masking tape, a few pieces of gravel rocks, a few pieces of iron ore (steel washers), a few assembled trees, (1) poster-sized sheet of sticky note paper, markers • **Per student:** (2) different colors or types of writing utensils, engineering notebook, Engineering Design Process slider	**DUPLICATION MASTERS** • 5.b. Selecting a Design Idea • 5.d. Evidence-Based Reasoning **EDUCATOR RESOURCES** • **(Optional)** 5.a. NWRM Lesson 5 Memo • 5.c. Selecting a Design Idea Rubric • 5.e. Evidence-Based Reasoning Rubric • 5.f. Evidence-Based Reasoning Instructions

Overview: Unit Overview

Lesson	Time Needed	Objectives The student will be able to:
6: Try a Solution	one 50-minute class period	• implement a design and create a prototype resource extraction tool. • add and multiply decimals to calculate the cost of the design, keeping the cost under $12.00.
7: Test a Solution	one 50-minute class period	• test their resource extraction tool prototypes. • convert improper fractions into mixed numbers to determine how many units of resource their tool prototype extracted. • determine the total area affected by the environmental impact of resource extraction by counting unit squares of disrupted ground cover.
8: Decide about a Solution	one 50-minute class period	• compare data about their design's performance with the performance of their peers' designs. • complete a chart to analyze the performance of their resource extraction tool prototypes.
9: Redesign	two-three 50-minute class periods	• use evidence from problem scoping, core science/mathematics concepts, and initial design test analysis to plan an improved design. • add and multiply decimals to calculate the cost of the improved design, keeping the cost under $12.00. • implement the design and create an improved resource extraction tool prototype. • test the performance of the improved solution. • determine the total area affected by the environmental impact of resource extraction by counting unit squares of disrupted ground cover. • convert improper fractions into mixed numbers to determine how many units of resource their improved tool prototype extracted. • compare data from their second design's performance with the performance of their initial design. • evaluate the alignment between their proposed solution and the problem.
10: Communicate to the Client	one 50-minute class period	• evaluate the alignment between their proposed solution and the problem. • communicate their design solution through the use of evidence-based reasoning. • justify why their design solution is appropriate based on application of core science/mathematics concepts, information obtained in problem scoping, and interpretation of acquired or gathered evidence.

Overview: Unit Overview

Materials	Duplication Masters & Educator Resources
• **Per classroom:** Engineering Design Process poster, toothpicks, craft sticks, paper clips, pipe cleaners, bamboo skewers, 3 oz. paper cups, mesh screens (2.5”x2.5”), magnets, 4”x6” notecards, rubber bands, string, masking tape, a few pieces of gravel rocks, a few pieces of iron ore (steel washers), a few assembled trees • **Per team:** scissors, (1) ruler • **Per student:** (2) different colors or types of writing utensils, engineering notebook, Engineering Design Process slider	**EDUCATOR RESOURCES** • **(Optional)** 6.a. NWRM Lesson 6 Memo • 6.b. Teacher Observation Protocol: Try Lesson
• **Per classroom:** Engineering Design Process poster, **(optional)** clear tape • **Per team:** (1) overhead transparency with cm2 grid copied, (1) overhead or dry erase marker, one prepared site, which includes: (1) medium plastic tub, approx. 10 lbs. sand, large gravel (~3/4”), steel washers, trees (each is one 1” pom-pom, one 2”x¼” dowel rod, one 1 oz. plastic cup), glue gun and glue, aquarium rocks • **Per student:** (2) different colors or types of writing utensils, engineering notebook, Engineering Design Process slider	**DUPLICATION MASTERS** • 7.c. Test Results • 7.d. Think About Results • Square centimeter grid sheet **EDUCATOR RESOURCES** • **(Optional)** 7.a. NWRM Lesson 7 Memo • 7.b. Teacher Observation Protocol: Test Lesson • 7.e. Think About Results Rubric
• **Per classroom:** Engineering Design Process poster • **Per student:** (2) different colors or types of writing utensils, engineering notebook, Engineering Design Process slider	**DUPLICATION MASTERS** • 8.b. Comparing with Other Teams • 8.c. Decide about a Solution **EDUCATOR RESOURCES** • **(Optional)** 8.a. NWRM Lesson 8 Memo • 8.d. Decide about a Solution Rubric
• **Per classroom:** Engineering Design Process poster, poster size sticky note paper with EBR template, (1) 5”x5” piece of mesh with small holes, toothpicks, craft sticks, paper clips, pipe cleaners, bamboo skewers, 3 oz. paper cups, mesh screens (2.5”x2.5”), magnets, 4”x6” notecards, rubber bands, string, masking tape • **Per team:** scissors, (1) ruler, (1) overhead transparency with cm2 grid copied, (1) overhead or dry erase marker, one prepared site, which includes: (1) medium plastic tub, approx. 10 lbs. sand, large gravel (~3/4”), steel washers, trees (each is one 1” pom-pom, one 2”x¼” dowel rod, one 1 oz. plastic cup), glue gun and glue, aquarium rocks • **Per student:** (2) different colors or types of writing utensils, engineering notebook, Engineering Design Process slider	**DUPLICATION MASTERS** • 9.b. Redesign: Evidence-Based Reasoning • 9.d. Redesign: Materials Cost Sheet • 9.e. Redesign: Test Results • 9.g. Redesign: Decide about a Solution **EDUCATOR RESOURCES** • **(Optional)** 9.a. NWRM Lesson 9 Memo • 9.c. Redesign: Evidence-Based Reasoning Rubric • 9.f. Teacher Observation Protocol: Redesign Lesson • 9.h. Redesign: Decide about a Solution Rubric
• **Per classroom:** Engineering Design Process poster, poster size sticky note paper with Evidence-Based Reasoning • **Per team:** If students are creating a poster, each team will need: (1) poster-sized sheet of paper, markers • **Per student:** (2) different colors or types of writing utensils, engineering notebook, Engineering Design Process slider	**DUPLICATION MASTERS** • **(Optional)** 9.b. Redesign: Evidence-Based Reasoning • 10.b. Reflect about Engineering Design **EDUCATOR RESOURCES** • 5.f. EBR Instructions • **(Optional)** 10.a. NWRM Lesson 10 Memo • 10.c. Reflect about Engineering Design Rubric

Master Material List

	Material	Lessons Where Material is Used
Per classroom	Engineering Design Process poster*	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
	(1) poster size sticky-note paper*	1, 5
	markers*	1, 5
	timer or clock*	2
	plastic spoons	3
	paper clips	3, 4, 5
	toothpicks	3, 4, 5
	craft sticks	3, 4, 5
	pipe cleaners	4, 5, 6
	bamboo skewers	4, 5, 6
	3 oz. paper cups	4, 5, 6
	mesh screens (2.5”x2.5”) with ~0.25” holes	4, 5, 6
	magnets	4, 5, 6
	4”x6” notecards	4, 5, 6
	rubber bands	4, 5, 6
	string	4, 5, 6
	masking tape	4, 5, 6
	(1) medium plastic tub	4
	approx. 10 lbs. sand	4
	large gravel (~3/4”)	4, 5, 6
	steel washers	4, 5, 6
	trees (each is one 1” pom-pom, one 2”x¼” dowel rod, one 1 oz. plastic cup)	4, 5, 6
	glue gun and glue	4
	aquarium rocks	4
	clear tape	7
	poster size sticky note paper with Evidence-Based Reasoning template*	9, 10
	(1) 5”x5” piece of mesh with small holes	9
Per team (assuming 3 students per team)	**(optional)** mini white board*	2
	(optional) dry erase marker*	2, 9
	(optional) sheets of paper*	2
	(optional) markers*	2, 10
	scissors	6, 9
	(1) ruler	6, 9
	(1) overhead transparency with cm^2 grid copied	7, 9
	(1) medium plastic tub	7, 9
	approx. 10 lbs. sand	7, 9

Master Material List

	Material	Lessons Where Material is Used
	large gravel (~3/4”)	7, 9
	steel washers	7, 9
	trees (each is one 1” pom-pom, one 2”x¼” dowel rod, one 1 oz. plastic cup)	7, 9
	glue gun and glue	7, 9
	aquarium rocks	7, 9
	toothpicks	9
	craft sticks	9
	pipe cleaners	9
	bamboo skewers	9
	3 oz. paper cups	9
	mesh screens (2.5”x2.5”)	9
	magnets	9
	4”x6” notecards	9
	rubber bands	9
	string	9
	masking tape	9
	(1) poster-sized sheet of paper	10
Per student	(2) different colors or types of writing utensils*	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
	engineering notebook*	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
	Engineering Design Process slider*	1, 2, 3, 4, 5, 6, 7, 8, 9, 10
	(1) rainbow chip/chocolate chip cookie*	3
	(1) paper plate	3

*required materials not included in kit

LESSON 1

Define the Engineering Problem

Lesson Objectives

Students will be able to:

- describe important features of an engineering design process.
- define an engineering problem from the perspective of stakeholders.
- generate and then refine a description of the problem based on new information.
- engage in problem scoping (i.e., define the problem and needs, and then identify the knowledge, criteria, and constraints required for a desirable solution).

Time Required

one-two 50-minute class period(s)

Materials

Per classroom:

- Engineering Design Process poster
- poster size sticky-note paper labeled "Questions for Client"
- markers

Per student:

- (2) different colors or types of writing utensils
- engineering notebook
- Engineering Design Process slider

Standards Addressed

Next Generation Science Standards: 3-5-ETS1-1, 3-5-ETS1-2

Key Terms

engineering design process, client, end-user, criteria, constraints, prototype

Lesson Summary

Students learn about the organized system of problem-solving steps called the engineering design process. By reading a letter from the client and asking the client additional questions, students learn about the specifics of their engineering problem, which is to create tools to extract resources from Planet Andoddin and select a site for extracting resources on the planet upon arrival. Using this information, students define the engineering problem, which includes identifying the problem and why it's important, client, end-users, criteria, constraints, and what else they need to learn in order to design effective solutions.

Background

Teacher Background

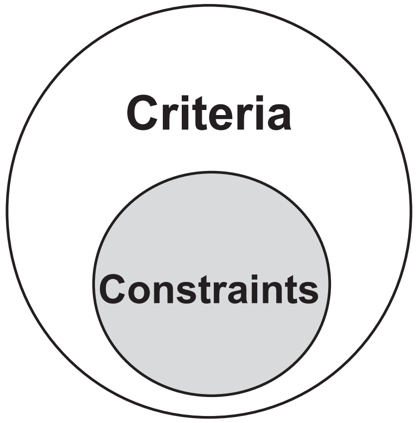
Teamwork: Students should be teamed strategically and may or may not be assigned roles within their team. When forming student teams, consider academic, language, and social needs. In place of strategic teaming, a random teaming can be substituted. Students will work in these teams, or "teams," of three or four throughout the unit. Effective teamwork is essential in this unit as well as in engineering in general; however, this unit does not provide specific support to develop those skills. If students do not have experience with teamwork, targeted team-building activities are highly recommended prior to beginning this unit.

Engineering Design Process: Students should have some familiarity with the engineering design process before beginning the unit. If they do not, the teacher will need to spend additional time explaining it, so this lesson may take more than one day. The engineering design process (EDP) is an iterative, systematic process used to guide the development of solutions to engineering problems. There is no single engineering design process, just like there is not one scientific method. However, the various engineering design processes have similar components. The engineering design process (EDP) is an iterative process that involves understanding the problem, learning background information necessary to solve the problem, planning, trying, testing the solution, making changes based on the tests, and communicating their ideas. Students will use a engineering design process slider throughout the unit to help them understand where they are in the design process. For more information about the steps of the engineering design process presented in this unit, see the front matter section about it.

Some common misconceptions about the EDP:

- Engineers do not have to learn anything new when they are working on a project.
    - **In reality:** Engineers need to continually learn throughout their lives.
- The engineering design process is linear, and you never need to go back to previous phases.
    - **In reality:** The EDP is a cyclical process that requires many iterations.
- Once engineers are done with a project, they never think about it again.
    - **In reality:** A project is never really "done," and engineers often continue to improve and make changes.

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



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

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

Solution Generation: The Solution Generation section of the engineering design process includes plan the solution, try out the plan of the solution, test the solution, and decide whether the solution is good enough. When engineers are generating solutions, they will use iteration as a means to continually improve their solution, reflect back on the problem definition and what they have learned about the problem, and consider criteria, constraints,

Assessments

Pre-Activity Assessment
Check students' verbal responses as they make observations and discuss their Engineering Design Process sliders.

Activity Embedded Assessment
Check students' progressive understanding through their verbal and written responses during the "Define the Problem" activity and discussions. This is particularly important when students are answering the *1.d. Define the Problem* worksheet questions, since they are doing so individually and in teams; circulate during this part of the activity and check their understandings as they emerge in the written responses and team conversations.

Post-Activity Assessment
Check students' verbal responses during the whole class discussion about their answers to the Define the Problem questions. Assess student answers to the *1.c. Questions for the Client* and the *1.d. Define the Problem* prompts using the *1.e. Questions for the Client and Define the Problem Rubric*

DUPLICATION MASTERS

- 1.a. What Do You Know About Engineers?
- 1.b. NWRM Client Letter
- 1.c. Questions for the Client
- 1.d. Define the Problem

EDUCATOR RESOURCES

- 1.e. Questions for the Client and Define the Problem Rubric
- 1.f. Define the Problem Answer Key

and trade-offs. Trade-offs involve having to make compromises about which criteria to emphasize because they compete with one another in terms of making the solution effective. For example, cost could be a trade-off for durability.

Engineering notebook: Throughout the unit students will be recording information in an engineering notebook, and they will need the notebook immediately in Lesson 1. Students' engineering notebooks will support their communication of ideas and should be used consistently throughout the unit. A number of worksheets are provided as duplication masters. If these worksheets are printed for students, they should be taped or stapled into their engineering notebooks so all of the unit information is stored within the notebooks.

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

An exoplanet is a planet that is outside our own solar system, which means it orbits a star other than the Sun. Planet Andoddin is a fictional exoplanet that is the focus of this unit. Space science is not the focus of this unit and thus, "exoplanet" is not a vocabulary word, but students may be unfamiliar with it and need to be introduced to what it means.

If this lesson needs to take two days instead of one, a recommended stopping point is after the students have shared their "Questions for the Client" with the whole class, but before the client responds with answers.

Before the Activity

Assemble the Engineering Design Process sliders (see the front matter for how to assemble them).

If using the duplication masters, print and make copies of the following worksheets in the labeled amounts:

- *1.a. What Do You Know About Engineers?* (1 per student)
- *1.b. NWRM Client Letter* (1 per student)
- *1.c. Questions for the Client* (1 per student)
- *1.d. Define the Problem* (1 per student)

If students are writing question prompts directly into their engineering notebooks, it is still recommended to make copies of 1.b.

Classroom Instruction

Introduction to the Unit

1. **Introduce the unit. Say:** *We will be working on an engineering project to locate and extract resources from an exoplanet called Andoddin in order to save the Earth.*

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.*

Define the Engineering Problem

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 you to assess the students and to 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. **Complete notebook prompts about engineering.** Pass out the *1.a. What Do You Know About Engineers?* worksheet and have students attach them in their notebooks, or provide students with the following two prompts to answer in their notebooks:
   - What do engineers do?
   - How do engineers solve problems?

   NOTE: Do this 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. See pages 136-138 for instructions for using notebooks rather than duplication masters.

Introduction

4. **Introduce engineering. Say/Ask:** *In order to create solutions to our problem, we will be working as engineers. What do you know about engineers?* Take student answers. **Say:** *Engineers are people who solve problems to help people by using science, mathematics, and creativity. These solutions are new or improved technologies, which can be objects or processes.*

5. **Introduce the engineering design process.** Display the *Engineering Design Process* poster and pass out *Engineering Design Process* sliders to each student. **Say:** *Engineers use an engineering design process, along with mathematics, science, and creativity, to understand a problem and come up with a solution. Since we are working as engineers during this unit, we will be using this engineering design process as a guide while we come up with a solution for our engineering problem.*

6. **Unpack the engineering design process.** Ask students to make observations about their Engineering Design Process sliders and then to share what they think the different parts mean. Guide discussion so that the following key points are noted:
   - The process can be broken down into two overall pieces: the Problem and the Solution (two gray boxes on the left).
   - The process is broken down into six steps: define (the problem), learn (about the problem), plan (the solution), try (the solution), test (the solution), and decide (whether the solution is good enough).

- Often, you go through the steps from one to the next one down (arrows in the middle).
- The process is iterative, or repeatable, meaning that you do not have to go exactly in order only one time (arrows along the sides).
- Communication and teamwork are important to the entire engineering design process (gray box on the right side).

NOTE: While this is not evident from the slider, it is important to inform students that there is not one single engineering design process. There are others, some with more steps, and some with fewer steps. They all have similar parts, though, such as iterating between the problem and solution, needing communication and teamwork throughout, and being repeatable.

7. **Identify where they are in the engineering design process. (Define)** **Say:** *Engineers need to first define the problem in detail before they can learn more about the problem and design a solution. This is what we will be doing today.*

Activity

8. **Introduce the problem.** Pass out the *1.b. NWRM Client Letter* to students. Read the letter using whatever method of reading is preferred (e.g., reading in small teams, teacher reading aloud to the whole class, volunteers in the class reading aloud to the whole team).

9. **Introduce the concept of prototype.** Point out that the student engineers have been asked to create a "tool prototype." Explain to students that a prototype is a testable representation of a solution, in this case it is a model of their design. They will not be creating life-size resource extraction tools out of industrial materials; instead, they will build a prototype, which is a smaller version made out of more easily available materials.

10. **Introduce the concepts of clients and end-users. Say/Ask:** *A "client" is a person or team who asks engineers to design something to solve a problem. This is different from the "end-users," which are the people who end up actually using the design solution. The client and end-users are both important to the engineering problem. According to this letter, who is our client? Who are the end-users?* NOTE: The client is Micah Bergmann, the president of New World Resource Management; he or she is asking the student engineers to solve the engineering problem. The end-users are NWRM workers who extract resources; they will actually use the tools at the sites chosen.

11. **Develop questions for the client. Say:** *We will not be able to speak with the end-users directly, but we now have an opportunity to ask the client questions about the problem so we can understand it better.* Pass out the *1.c. Questions for the Client* worksheet and have students attach it in their notebooks, or have them write the prompt: *"What questions do you want to ask the client?*" in their notebooks. Have the students answer the prompt, whether on the worksheet or written directly in the notebooks, by developing a list of questions to ask the client. Give them time to share their list with their team and develop a team set of questions. Students can use different

colored pens for their own response and their team's response.

12. **Share questions.** As a whole team, share these questions. Record students' questions for the client on chart paper labeled "Questions for Client". Leave space near each question for its answer to be recorded later. Possible questions students could ask (as well as their corresponding answers) are listed below. Students are not expected to ask all of these questions; however, it is important that the limited materials and money are addressed at this time. If the class has not thought of these two possibilities, guide them toward asking questions about supplies available and cost. Students may also ask questions not on this list. Use your judgment to answer them.
    Possible questions and appropriate responses (*client answer in italics*):
    - What materials can we use? *Your teacher has a list of materials that you can use for your tool prototype. We ask that you stick to these materials.*
    - How much money can we spend? *Your budget is $12.00. The less money you spend, the better.*
    - What resources will we be extracting? *Wood, iron ore, and gravel rocks. Each team of student engineers will only be assigned one resource to focus on for their tool design and site selection, but as a whole class, we want to see designs for all three types of resources.*
    - What is Andoddin like? *It is mostly sand, but there are iron ore and gravel rocks in the sand. There are trees with roots and leaves on some of the surface. The rest of the surface is covered with a material that is very important to Andoddin's environment.*
    - How much time will we have to extract the resources? *You will have 10 minutes to test your prototypes.*
    - Do the tools need to look nice? *No. Appearance doesn't matter to NWRM.*
    - What size should the tools be? *Smaller tools would be easier to transport to Andoddin, but this is not a huge factor in our decision.*
    - What shape do the tools need to be? *It is up to you.*
    - Does it matter how easy the tool is to make? *The easier the tool is to create, the better, but this is not a huge factor in our decision.*

13. **Provide answers to students' questions for the client.** This may be done in several ways. This includes, but is not limited to: including the client answers on the day's memo; pretending to call the client and ask the questions; telling the students that the client has already provided a list of answers to questions they anticipated student engineers would ask; inviting a guest speaker to pretend to be the client and answer students' questions.

14. **Record the client's answers.** Record the answers to the questions on the chart paper labeled "Questions for Client", preferably in a different color than the questions. NOTE: If students continue to ask questions about the problem in later lessons, write the questions and answers on the "Questions for Client" chart paper. Keep this chart on display as a reminder to students about the criteria and constraints of the problem.

Define the Engineering Problem

15. **Define the problem, including identifying the client and end-users.** Pass out the *1.d. Define the Problem* worksheet and have students paste them in their notebooks, or provide students with the prompts to answer in their notebooks. **Say:** *Let's review what we have learned about the problem so far from the letter and the questions we asked the client.* Ask students to individually answer the questions on the *1.d. Define the Problem* worksheet up to the questions about criteria and constraints. When students finish answering the questions on their own, instruct them to share their responses in small teams, decide what their team answer is, and write down that possibly revised answer on the *1.d. Define the Problem* worksheet or directly in their engineering notebooks. (**Optional)** If a student team seems to be struggling with a question, address it as a whole class.

16. **Describe the criteria and constraints of the problem. Say:** *The "criteria" of an engineering problem are the requirements, or goals, of the designed solutions. The criteria help us decide whether the solution has solved the problem. The "constraints" of an engineering problem are the things that limit the design possibilities.* Ask students to individually answer the questions about criteria and constraints on the *1.d. Define the Problem* worksheet or respond to the prompts in their engineering notebooks. When students finish answering the questions on their own, instruct them to share their responses in small teams, decide what their team answer is, and write down that possibly revised answer on the *1.d. Define the Problem* worksheet or directly in their engineering notebooks. **(Optional)** Determine one criterion and one constraint as a whole class, so students have an example to clarify what criteria and constraints are.

17. **Describe the background knowledge needed. Say/Ask:** *Today we have learned a lot about the problem from the client. However, we need to learn more before we start designing solutions to the problem. What else do you think we need to learn in order to create a tool to extract resources with little environmental impact from Planet Andoddin?* Ask students to individually answer the final question on the 1.*d. Define the Problem* worksheet, generating ideas about the kinds of information they still need to learn. When students finish answering the questions on their own, instruct them to share their responses in small teams, decide what their team answer is, and write down that possibly revised answer on the *1.d. Define the Problem* worksheet or directly in their engineering notebooks. **(Optional)** As a whole class, have teams share ideas about what background information they think they need to learn in order to extract resources from the exoplanet Andoddin.

Closure

18. **Review the problem.** As a whole class, discuss the answers students have provided in *1.d. Define the Problem* worksheet or directly in their engineering notebooks. Emphasize that in order for engineers to solve to a problem, they need to deeply understand the problem first. Defining the problem is critical to the work of engineers.

Define the Engineering Problem

LESSON 1

LESSON 1

Name________________________________ Date___________ Period _____

1.a. What Do You Know About Engineers?

Directions: Answer the questions as best as you can.

1. What do engineers do?

2. How do engineers solve problems?

LESSON 1

Name________________________________ Date___________ Period _____

1.c. Questions for the Client

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

Name_____________________________ Date__________ Period _____

LESSON 1 — 1.b. NWRM Client Letter

NWRM New World Resource Management

Dear Student Engineers,

My name is Micah, and I am the president of New World Resource Management. Our company would like to hire you for one of our projects.

The Earth is slowly running out of natural resources. We need resources to help life continue on Earth. Our company's advanced long-range scanners have found an uninhabited exoplanet that has resources we need. We call this planet Andoddin. Your assignment is to help us extract these resources from Andoddin.

As a signer of the 1998 Protocols on Intergalactic Ethics (PIE), all Earth contractors have permission from the Federation of Intergalactic Exoplanets (FIE) to conduct preliminary resource extraction activities on Andoddin. FIE recognizes that Earth is technologically advanced, and is therefore interested in inviting an Earth contractor to help responsibly develop Andoddin's resources.

There are several parts to this project. First, you will need to choose which sites on Andoddin will be best to extract resources from. Second, you will design tools that our NWRM workers can use to extract these resources. Our long-range scanners have also discovered that the surface of Andoddin is covered in a layer of material that is extremely important to Andoddin's environment. We want the resource extraction tool prototypes you design to get as many resources as possible, but we also want them to not do much damage to Andoddin's surface. Third, when you communicate your final design to us, you will need to justify your design with evidence.

Sincerely,

Micah Bergmann

Micah Bergmann, President
New World Resource Management

LESSON 1

Name________________________________ Date___________ Period _____

1.d. Define the Problem (1/2)

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? Explain why this is important to solve. Use information from your client to support your reasons.

   My response:

   Team response:

3. Who are the end-users?

   My response:

   Team response:

LESSON 1

Name_________________________________ Date____________ Period _____

1.d. Define the Problem (2/2)

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

   My response:

   Team response:

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

   My response:

   Team response:

6. Think about the problem of extracting resources on planet Andoddin. In terms of not damaging the surface of Andoddin, what are at least 2 things you need to learn in order to design a tool successfully? Make sure to consider all important aspects of the problem. Be specific.

   My response:

   Team response:

Student Name_______________________________ Date__________ Period _____

1.e. Questions for the Client and Define the Problem Rubric

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

LESSON 1

Student Name________________________ Date__________ Period _____

1.e. Questions for the Client and Define the Problem Rubric

Problem	Question	Learning Objectives	Rubric	
1.d.5	What will limit how you can solve the problem (constraints)? Use detailed information you have from the client.	Explain constraints based on information.	yes no	**Identified at least 1 constraint**
			yes no	**Connected information from client to constraints**
1.d.6	Think about the problem of extracting resources on planet Andoddin. In terms of not damaging the surface of Andoddin, what are at least 2 things you need to learn in order to design a tool successfully? Make sure to consider all important aspects of the problem. Be specific.	Explain the background knowledge needed to develop a solution.	**Identified at least 2 topics they needed to learn** CIRCLE: 0 1 2 3 +	
			Topics are relevant to the problem CIRCLE: 0 1 2 3 +	
			Considered at least 2 different aspects of the problem CIRCLE: 0 1 2 3 +	

Notes:

1.d. Define the Problem Answer Key

1. **Who is the client?**

   The client is Micah Bergmann, the president of New World Resource Management.

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

   The problem is that the Earth is running out of natural resources. NWRM has found a planet that may help with a solution to this problem. They need us to choose a site to extract resources from. They also need us to design tool prototypes to extract a lot of resources, but also not do much damage to the surface of Andoddin. We also need to justify our design with evidence. The problem is important to solve because Earth is running out of resources. We need resources to help life continue on Earth.

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

   The end-users are the NWRM workers, who will use the tools to extract resources from Andoddin.

4. **What will make the solution effective (criteria)?**

   The tools need to extract as many resources as possible. The tools also have to do as little damage to Andoddin's surface as possible. It needs to cost less than $12.00.

5. **What will limit how you can solve the problem (constraints)?**

   We can only use materials on the list. Our prototype needs to cost as little as possible and do not much damage to Andoddin's surface. It cannot cost more than $12.00.

6. **Think about the problem of extracting resources on planet Andoddin. In terms of not damaging the surface of Andoddin, what are at least 2 things you need to learn in order to design a tool successfully? Make sure to consider all important aspects of the problem. Be specific.**

   This will not be graded on the correctness of the answer, just that it is clear that students are thinking about what information would help them design. Answers will be graded based on number of topics identified, relevance to the problem, and number of problem aspects considered.

   Answers vary, but may include: what are different types of resources, how are resources extracted here on Earth, how do these technologies do less damage to Earth's environment, etc.

LESSON

2 Renewable and Nonrenewable Resources

Lesson Objectives

Students will be able to:

- define natural resources.
- describe the difference between renewable and nonrenewable natural resources.
- identify whether natural resources are renewable or nonrenewable.

Time Required

one 50-minute class period

Materials

Per classroom:

- Engineering Design Process poster

Per team:

- **(optional)** mini white board
- **(optional)** dry erase marker
- **(optional)** sheets of paper
- **(optional)** marker

Per student:

- (2) different colors or types of writing utensils
- engineering notebook
- Engineering Design Process slider

Standards Addressed

Next Generation Science Standards: 4-ESS3-1, *MS-ESS3-1

Key Terms

- Primary: natural resources, renewable resources, nonrenewable resources
- Secondary: reusable resources, conserve, fossil fuel

Lesson Summary

Students read and analyze an article in order to learn about natural resources and renewable and nonrenewable resources. They then apply that knowledge by identifying renewable and nonrenewable material and energy resources.

Background

Teacher Background

It may be helpful to read through the *Renewable and Nonrenewable Resources* reading as a review of renewable vs. nonrenewable resources.

Some students may believe that Earth's resources are not actually finite and that we can always find more if we look hard enough. They may confuse the difference between renewable and nonrenewable resources due to the time frames involved with replenishing certain resources (i.e., If fossil fuels originated from plant and animal remains, shouldn't they be considered renewable?). They may not recognize a connection between manufactured products and the resources that were used to make them, or realize that the outcome of increased manufacturing is the decreased availability of resources. Students may also be unsure how recycling certain materials and cleaning water factors into whether we consider resources renewable or not. The complex differences in how we can acquire and process resources, how we can dispose of products in various ways, and the impact of our actions on future availability of resources may also be important to consider with students.

The difference between renewable and nonrenewable resources and energy, while not a mastery concept in this lesson, is important to the second part of the activity. Some natural resources help provide energy. Some provide other things that people need - water, wood, gravel, etc. Some natural resources may do both. For example, water can be used to generate electricity (hydropower), but we use water for many other uses as well. In this way, water is a renewable resource and a source of renewable energy.

Before the Activity

If using the duplication masters, print and make copies of the following worksheets in the labeled amounts:

- *2.b. Natural Resources Vocabulary* (1 per student)
- *2.d. Identify Renewable and Nonrenewable Resources* (1 per student
- *2.f. Natural Resources Exit Slip* (1 per student)

NOTE: Other vocabulary layouts (e.g., the Frayer model) could be used in place of *2.b. Natural Resources Vocabulary.*

(Optional) The resources provided on *2.d. Identifying Renewable and Nonrenewable Resources* and *2.f. Natural Resources Exit Slip* can be changed to other resources (e.g., resources that are locally important).

Also, print and make copies of the following reading in the labeled amounts:

- *Renewable and Nonrenewable Resources* (1 per student)
  Available from the Penn State University Extension website: http://extension.psu.edu/publications/uh177/view

NOTE: This article is also viewable electronically at this link, so students could read it using digital technologies if that is preferred.

Renewable and Nonrenewable Resources

LESSON 2

Load the website for the resource activity:

- http://www.childrensuniversity.manchester.ac.uk/interactives/science/energy/renewable/

NOTE: You may have to install Adobe Flash Player in order to use this website.

An alternative online resource for this activity can be found at: https://www.brainpop.com/games/sortifynaturalresources/. This online resource can also be used to sort resources depending on whether they are nonrenewable or renewable. Play the game(s) before the lesson to provide better instructions to students.

Classroom Instruction

Introduction

1. **(Optional) Read the daily memo from NWRM.** Read the daily memo, *2.a. NWRM Lesson 2 Memo*, out loud to the students, highlighting the objective for that day's mission and the focus question.

2. **Tie to the engineering problem. Ask:** *What is our engineering design problem?* Take students' answers.

3. **Identify where they are in the engineering design process. (Learn) Say/Ask:** *So far, we have defined the problem in detail with help from our client.* Point out the "Define" block on engineering design process, and have students look at their Engineering Design Process sliders. *Before we can start designing solutions, though, we need more information. What step of the engineering design process do we need to do next?*

4. **Identify what students need to learn about. Say/Ask:** *In the previous lesson, you all identified what we need to learn about. What were some of those ideas we need to learn?* Remind students to refer to their notes from the previous lesson, specifically the last question of problem scoping. Students should say something about resources, environmental impact, etc.

Activity

Part 1: Renewable and Nonrenewable Reading and Activity

5. **Pass out the reading materials.** Pass out the *Renewable and Nonrenewable Resources* article and *2.b. Natural Resources Vocabulary* to students.

6. **Read the article.** Using whatever method of reading is preferred (e.g., reading in small teams, teacher reading aloud to the whole class, volunteers in the class reading aloud to the whole team), read the article.

7. **Do the vocabulary activity.** Have students write down each of the three main vocabulary words - natural resources, renewable resources, and nonrenewable resources - as well as their definitions on *2.b. Natural Resources Vocabulary* or in their engineering notebooks NOTE: Other vocabulary graphic organizers and activities (e.g., Frayer model) could be

Assessments

Pre-Activity Assessment

Students should have their engineering notebooks and/or worksheets from the previous lesson. What engineering problem are we tasked with solving? Check that students can state the defined problem.

Activity Embedded Assessment

Check students' progressive understanding though their verbal and written responses during activities and discussions. In particular, pay attention to their explanations as to how they know whether a resource is renewable or nonrenewable, which will be written on the *2.d. Identify Renewable and Nonrenewable Resources* worksheet or directly into their engineering notebooks, as well as discussed during the animation game activity.

Post-Activity Assessment

Post-Activity Assessment: Collect and sort the 2.*f. Natural Resources Exit Slip*, identifying common student misconceptions and students who still need practice with resources concepts.

DUPLICATION MASTERS

- 2.b. Natural Resources Vocabulary
- 2.d. Identify Renewable and Nonrenewable Resources
- 2.f. Natural Resources Exit Slip

EDUCATOR RESOURCES

- **(Optional)** 2.a. NWRM Lesson 2 Memo
- 2.c. Natural Resources Vocabulary
- 2.e. Identify Renewable and Nonrenewable Resources
- 2.g. Natural Resources Exit Slip

used in place of *2.b. Natural Resources Vocabulary.*

8. **Introduce the identifying resources activity.** Pass out *2.d. Identify Renewable and Nonrenewable Resources* to students, or have students write down the three resources in their engineering notebooks. **Say:** *Now we are going to practice identifying whether resources are renewable or nonrenewable.*

9. **Complete the worksheet.** For each resource - wood, water, and minerals - have students identify whether the resource is renewable or nonrenewable and how they know that. NOTE: This can be done as a whole class activity, or students can work in small teams. If students work in small teams, have the teams share their identification and reasoning with the whole class after they have all finished. In either situation, emphasize the differences between renewable and nonrenewable resources.

Part 2: Animation Game

10. **Introduce the animation activity.** Open the *Renewable and Nonrenewable Energy* game online. Tell students that they are going to have more practice identifying whether something is renewable or nonrenewable.

11. **Clarify the difference between renewable and nonrenewable resources and energy. Say:** *So far, we have been talking about renewable and nonrenewable resources. People also think and talk about renewable and nonrenewable energy. Renewable energy is energy that comes from renewable resources, and nonrenewable energy is energy that comes from nonrenewable resources.*

12. **Read the definitions of nonrenewable sources and renewable sources.** Read aloud to the students or ask a student volunteer to read the explanations of nonrenewable sources and renewable sources, two slides in the animation.

13. **Sort the sources of energy.** For each source of energy, display it and read the description. Have students work in pairs (e.g., Turn and Talk) or small teams to determine whether the source of energy is renewable or nonrenewable. If there are sources that students are struggling with, have a whole class discussion about that source of energy to clarify why it is either renewable or nonrenewable before moving on to the next slide in the animation.
    - **(Optional)** Have each pair or small team write down each of their answers on a notebook page or a mini whiteboard and display it to the teacher.
    - **(Optional)** This activity could be done as a team game with points assigned for correct answers.

14. **(Optional) Do the quiz at the end of the animation.** There is an eight-question quiz in the animation after the sorting activity. The first four questions of the quiz ask the player to define renewable and nonrenewable sources and then identify a list of each; these are directly relevant

to the lesson and could be a good review for students. The second four questions are questions about specific details of certain types of resources; they are not necessary for the lesson, but students might find them interesting. NOTE: The quiz will not be avaliable if the Children's University of Manchester link to the resources activity was not used or functional.

Closure

15. **Fill out the exit slip.** Pass out one copy of the *2.f. Natural Resources Exit Slip* to each student. Read through the questions aloud as students mark their responses. Collect the exit slips.

LESSON 2

Name______________________________ Date__________ Period _____

2.a. NWRM Lesson 2 Memo

NWRM New World Resource Management

Dear Student Engineers,

Thank you for turning in your first assignment as an employee of the company. We are pleased that you are thinking deeply about the engineering problem and already have some background knowledge of resources. However, to ensure that your mission to Andoddin is successful, we need you to familiarize yourself even more with the idea of "natural resources", so that you can learn more about the wood, iron ore, and gravel we chose to extract.

Please study the following article and participate in the computer-based simulation to fill your brain with the information required by us, NWRM. The virtual simulation will be guided by your teacher, but your task is to answer the questions as efficiently as possible.

As a reminder, company employees are required to leave identifying marks on completed forms and to fill those forms out as thoroughly as possible.

Focus Question: What are resources and why do we need them?

Mission Objective: Define natural resources and identify them as renewable or nonrenewable.

Sincerely,

Micah Bergmann

Micah Bergmann, President
New World Resource Management

LESSON 2

Name________________________________ Date___________ Period _____

2.b. Natural Resources Vocabulary

Directions: Write each vocabulary word and its definition.

2.c. Natural Resources Vocabulary Answer Key

Directions: Write each vocabulary word and its definition.

Word	Definition
Natural Resources	materials or things people can use that come from nature/the Earth
Renewable Resources	resources that can grow again or can never run out
Nonrenewable Resources	resources that can be used up, can run out, or cannot be grown again

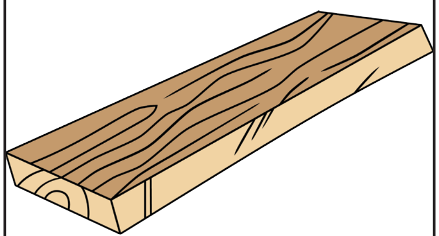
Exact definitions may vary

LESSON 2

Name____________________ Date__________ Period _____

2.d. Identify Renewable and Nonrenewable Resources

Are these natural resources renewable or nonrenewable?



Wood

Is it renewable or nonrenewable?

____

How do you know it is renewable or nonrenewable?

____

____

Water

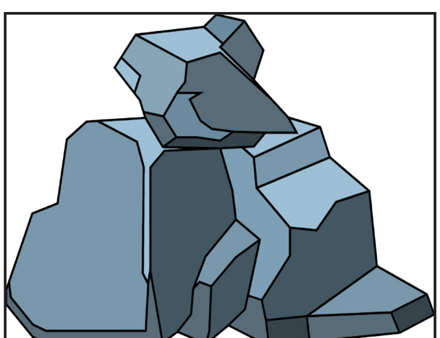
Is it renewable or nonrenewable?

____

How do you know it is renewable or nonrenewable?

____

____



Minerals

Is it renewable or nonrenewable?

____

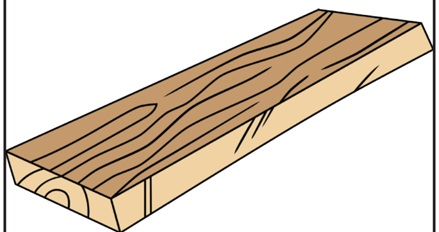
How do you know it is renewable or nonrenewable?

____

____

2.e. Identify Renewable and Nonrenewable Resources Answer Key

Are these natural resources renewable or nonrenewable?



Wood

Is it renewable or nonrenewable?

Renewable

How do you know it is renewable or nonrenewable?

Wood comes from trees, which can grow again.

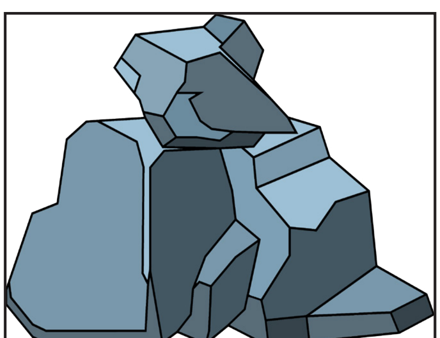
Water

Is it renewable or nonrenewable?

Renewable

How do you know it is renewable or nonrenewable?

Water is renewed by moving in cycles.



Minerals

Is it renewable or nonrenewable?

Nonrenewable

How do you know it is renewable or nonrenewable?

Minerals come from the ground. There are fixed amounts so they can be used up. They do not grow.

LESSON 2

Name________________________________ Date__________ Period _____

2.f. Natural Resources Exit Slip

1. Explain the difference between renewable resources and nonrenewable resources.

2. Is **coal** renewable or nonrenewable? ____________________
   How do you know?

3. Is **corn** renewable or nonrenewable? ____________________
   How do you know?

LESSON 2

Name________________________________ Date__________ Period _____

2.f. Natural Resources Exit Slip

1. Explain the difference between renewable resources and nonrenewable resources.

2. Is **coal** renewable or nonrenewable? ____________________
   How do you know?

3. Is **corn** renewable or nonrenewable? ____________________
   How do you know?

2.g. Natural Resources Exit Slip Answer Key

1. Explain the difference between renewable resources and nonrenewable resources.
   We will not run out of renewable resources because they can grow again or never run out. We can run out of nonrenewable resources because they can be used up and cannot grow again.

2. Is coal renewable or nonrenewable? ___ Nonrenewable____
   How do you know?
   There is a limited amount of coal in the ground. It will be used up after we dig it all out.

3. Is corn renewable or nonrenewable? _____ Renewable_____
   How do you know?
   New corn can be grown from seeds, so we will not run out of it.

LESSON 3

Resource Extraction: Cookie Mining

Lesson Objectives
Students will be able to:
- describe mining as the process of extracting resources from the ground.
- explain environmental impact and how mining decisions affect the environment.
- add, subtract, and multiply costs with decimals to calculate profit.

Time Required
One 50-minute class period

Materials
Per classroom:
- Engineering Design Process poster
- timer or clock
- materials students can purchase for cookie mining, so need at least a few per student:
  - paper clips
  - toothpicks
  - plastic spoons
  - craft sticks

Per student:
- (1) rainbow chip/chocolate chip cookie
- (1) paper plate
- (2) different colors or types of writing utensils
- engineering notebook
- Engineering Design Process slider

Standards Addressed
- Next Generation Science Standards: 4-ESS3-1
- Common Core State Standards – Mathematics: 4.MD.A.2

Key Terms
mining, environmental impact

Lesson Summary
Students complete a cookie mining activity to learn about the environmental impact of extracting resources. They purchase cookies and mining tools, then extract as many chocolate and rainbow chips from the cookies in a given time. Students calculate the cost of the cookies and tools, as well as the profit earned depending on how many chips they mine. The activity teaches students about the environmental impact of mining and explains the importance of extracting resources using low impact methods.

Background
Teacher Background
Renewable and nonrenewable natural resources are distributed across the world, and are essential for plant, animal, and human life. Some of these resources can be used by people as fuel, energy, and raw materials. Mining is a way to extract natural resources like coal, oil, and minerals from the Earth. Underground mining removes resources deep within the earth by digging shafts, while surface mining methods (such as strip mining, mountaintop mining, or dredging) extract resources that are close to the surface by removing the rock, soil, and ground cover above them. Environmental impact is an important consideration during mining, and miners should choose methods that cause minimal damage and disruption to the Earth's systems.

The cookie is a representation of a conglomerate, which is a coarse-grained sedimentary rock that is made up of larger fragments (chocolate chips and rainbow chips) within a matrix of finer grained material (the cookie). If students have already learned about rocks and minerals, this could be discussed as a review of that.

Before the Activity
Safety: Find out about allergies of students to make sure using cookies is safe.

If using the duplication masters, print and make copies of the following worksheets in the labeled amounts:
- *3.b. Cookie Mining Cost Sheet* (1 per student)
- *3.c. Cookie Mining Questions* (1 per student)

If students are writing question prompts directly into their engineering notebooks, it is still recommended to make copies in the specified amounts for 3.b.

Set up a shopping area with the cookies and mining tool materials, with the price of each item marked. Have cookies on individual paper plates, or give each student a plate before the activity. **(Optional)** If there are limited amounts of mining tool materials, place a cap on how many mining tools each student can purchase.

Have a timer ready and set to 10 minutes, or use a clock to watch 10 minutes pass.

Resource Extraction: Cookie Mining

LESSON 3

Load websites to show students different types of modern mining equipment:

- http://www.greatmining.com/mining-equipments.html
- http://www.coaleducation.org/technology/modern_equipment.htm
- https://mineralseducationcoalition.org/mining-minerals-information/all-about-mining/

(Optional) Load websites about space mining if you are choosing to introduce space mining. Review the following websites and choose your favorite:

- **NASA New World Atlas:**
  - https://exoplanets.nasa.gov/newworldsatlas/
- **Asteroid mining:**
  - https://open.nasa.gov/blog/awesome-stuff-in-space-planet-mining-gone-wild/
  - http://www.bbc.com/future/story/20160103-the-truth-about-asteroid-mining
- **Audio about space mining:**
  - (27 minutes) https://www.washingtonpost.com/business/space-mining-may-be-only-a-decade-away-really/2017/04/28/df33b31a-29ee-11e7-a616-d7c8a68c1a66_story.html?utm_term=.f9a381f0a414
  - (3 minutes) http://www.bbc.co.uk/programmes/p04yzrr7
- **Space prospecting:**
  - https://earthobservatory.nasa.gov/Features/ASTERProspecting/
- **What could we mine in space?:**
  - http://www.bbc.co.uk/programmes/p04zz3tv
- **Mining lunar ice:**
  - https://www.ted.com/talks/bill_stone_explores_the_earth_and_space

Classroom Instruction

Introduction

1. **(Optional) Read the daily memo from NWRM.** Read the daily memo, *3.a. NWRM Lesson 3 Memo*, out loud to the students, highlighting the objective for that day's mission and the focus questions.

2. **Tie to the engineering design problem. Ask:** *What is our engineering design problem?* Take student answers.

3. **Identify where students are in the engineering design process. (Learn)** Use the *Engineering Design Process* poster and students' *Engineering Design Process* sliders to help students identify what they have done so far and what step they are currently on. **Ask:** *Based on what we have talked about so far, what other science do we need to learn about?*

4. **Review the concept of renewable and nonrenewable resources.** Ask students to explain what they have previously learned about renewable and nonrenewable natural resources and what makes them different from each other. Have them give examples of each, and discuss as a class how people use these resources.

Assessments

Pre-Activity Assessment
Check students' understanding of natural resources and renewable vs. nonrenewable resources, as well as the details of the engineering design problem during the discussions in the introduction.

Activity Embedded Assessment
Check students' progressive understanding through their verbal and written responses during the Cookie Mining activity and discussions, especially when they discuss and write about the environmental impact that mining has.

Post-Activity Assessment
Check students' understanding through their responses during the natural resources and environmental impact discussion at the end of class.

DUPLICATION MASTERS

- 3.b. Cookie Mining Cost Sheet
- 3.c. Cookie Mining Questions

EDUCATOR RESOURCES

- **(Optional)** 3.a. NWRM Lesson 3 Memo

Resource Extraction: Cookie Mining

5. **Introduce the concept of mining. Say:** *For natural resources to be used by people, they must first be extracted from the Earth. Some of these resources, like coal, oil, and minerals, can be removed using a process called "mining". When resources are buried deep inside the Earth, miners dig tunnels to reach them and work underground to remove them. Other times, the resources are near the surface, and miners can remove the rock and soil from above to reach them. When a company prepares to mine, they want to choose the least expensive method that will get them as many resources as possible.*

6. **Explore modern mining equipment.** Show students pictures of different kinds of equipment that real mining companies currently use (links in the "Before the Activity" section). Discuss the differences between tools that are used for underground mining, which dig shafts and tunnels, and tools that are used for surface mining, which remove the surface covering the resources.

7. **Discuss environmental impact. Ask:** *How do you think digging for resources below the Earth's surface could affect the people, animals, and plants living on it?* Take student answers. Discuss as a class problems such as pollution of the ground and water, relocation of human and animal homes, and removal of plant life. **Say:** *The change that mining causes to the Earth is called its "environmental impact". Low environmental impact will only damage the Earth a little, but high environmental impact will cause a lot of damage to the Earth.* **(Optional)** Depending on students' background knowledge, this discussion could also include ways that ecosystems and food chains might be imbalanced by mining.

8. **(Optional) Introduce space mining.** Show students videos for space mining, have students read websites in teams or as a class, and/or play the audio programs. Discuss the types of resources mined from exoplanets and asteroids. Think about the characteristics of exoplanets that make them easy or difficult to extract resources from. Consider whether or not resources mined in space are transported back to Earth.

Activity

9. **Introduce the activity.** Pass out one *3.b. Cookie Mining Cost Sheet* to each student or have students create a similar data table in their engineering notebooks. **Say:** *You are going to practice mining by removing resources from a plot of land. The land is represented by cookies. Chocolate chips and rainbow chips are two different types of resources, and they are worth different amounts of money. You will need to purchase one plot of land (a cookie) and buy one or more mining tools that will help you extract the most resources, since you cannot use your hands to dig out the resources. You will have 10 minutes for mining.* Have students look at their cost sheets to see how valuable chocolate and rainbow chips are.

10. **Choose cookies and tools.** Let each student select a cookie. Students should also purchase one or more mining tools. Make sure they record how many of each they buy in the data table, which is either in *3.b. Cookie*

Mining Cost Sheet or written in their engineering notebooks.

11. **Mine the cookies.** Students should remove as many chips from the cookies as they can in 10 minutes, using only their purchased mining tools, no hands or other items. Remind them that whole chips are worth more than pieces, so they should try not to break any. NOTE: The 10 minutes can be measured using a pre-set timer or a clock. Also, when students are finished, have them leave the cookie pieces and chips on the plate. They will need to count the number of chips in the next step and later examine and draw their cookies.

12. **Record the number of chips removed.** Have students count the number of whole chocolate and rainbow chips and pieces, and record the number of each in their cost data tables. NOTE: Teachers may wish to provide another small object (e.g., a pea, an aquarium rock) to be a standardized "measure" for students to compare their pieces with and decide if they are big enough to be counted.

13. **Calculate the profit earned from mining.** Calculate the "Total Mining Cost" by first multiplying the quantity of each tool by its price and then adding all prices. Calculate the "Total Mining Payment" by first multiplying the quantity of each chip type by its payment and then adding all payments. Subtract the "Total Mining Cost" from the "Total Mining Payment" to compute how much they have earned from mining. NOTE: If students are already comfortable with multiple and adding decimals related to cost, these calculations may be done individually or in small teams. If students are less comfortable, this can be done as a whole class activity with the teacher guiding them through each step.

14. **Reflect on the activity.** Pass out one *3.c. Cookie Mining Questions* worksheet to each student, or have students copy the four questions into their engineering notebooks. Students should answer each question. NOTE: Students may eat the remains of their cookies after Question 2 is complete.

15. **Discuss answers to the questions.** Have students share their answers in a whole class discussion. Focus on the environmental impact of mining and how it could be a tradeoff with cost.

Closure

16. **Review all science concepts**. Lead a whole class discussion in which students share their understanding of natural resources, identifying renewable vs. nonrenewable resources, mining, and environmental impact.

3.a. NWRM Lesson 3 Memo

NWRM New World Resource Management

Dear Student Engineers,

Congratulations! You have done a great job learning about resources, why we need them, and the difference between renewable and nonrenewable resources. Now you need to learn about how resources are removed from the ground. Today you will take a conglomerate item and remove as many individual parts as possible. You will have a limited selection of tools available at this point, so you must be careful and take your time.

You will also need to think about how extracting resources from the ground affects the environment. During today's mining challenge, you will need to try to make your environmental impact as small as possible. By learning about mining and how it impacts the environment, you will be more prepared for designing a resource extraction tool prototype for use on the exoplanet Andoddin.

Focus Questions: How do we get resources out of the ground? What impact does this have on the environment?

Mission Objective: Describe what mining is and how it affects the environment.

Sincerely,

Micah Bergmann

Micah Bergmann, President
New World Resource Management

Name________________________________ Date____________ Period ______

3.b. Cookie Mining Cost Sheet

			Cost:
Plot of Land (cookie)			$7.00
Mining Tools:	**Number:**	**Price:**	
Paper Clip		x $3.00 =	
Toothpick		x $2.00 =	
Spoon		x $1.00 =	
Craft Stick		x $1.00 =	
	Total Mining Cost:		
Chip Removal	**Number:**	**Payment:**	
Whole Chocolate Chips		x $2.00 =	
Whole Rainbow Chips		x $1.00 =	
Chocolate Chip Pieces		x $1.00 =	
Rainbow Chip Pieces		x $0.50 =	
	Total Mining Payment:		
Mining Profit			
Total Mining Payment - Total Mining Cost:		=	

LESSON 3

Name________________________________ Date___________ Period _____

3.c. Cookie Mining Questions

1. Are the chocolate and rainbow chips renewable or nonrenewable resources? How do you know?

2. What did your cookie look like after you removed the chips?

3. What could you change in your mining to make a bigger profit?

4. Imagine your cookie is the Earth’s surface. What is the environmental impact of your mining?

LESSON 4 Site Selection & Tool Design Idea Generation

Lesson Objectives

Students will be able to:

- use cross-sectional maps to identify where their assigned resource is located at each site.
- justify their decision about which site they will extract their resource from.
- use evidence from problem scoping to generate multiple initial ideas for a design solution.
- add and multiply decimals to calculate the cost of the design.

Time Required

One 50-minute class period

Materials

Per classroom:

- EDP poster
- one prepared site, which includes:
  - (1) medium plastic tub
  - approx. 10 lbs. sand
  - large gravel (~3/4”)
  - steel washers
  - trees (each is one 1” pom-pom, one 2”x¼” dowel rod, one 1 oz. plastic cup)
  - glue gun and glue
  - aquarium rocks
- materials available for design:
  - toothpicks
  - craft sticks
  - paper clips
  - pipe cleaners
  - bamboo skewers
  - 3 oz. paper cups
  - mesh screens (2.5”x2.5”)
  - magnets
  - 4”x6” notecards
  - rubber bands
  - string
  - masking tape

Per student:

- (2) different colors or types of writing utensils
- engineering notebook
- EDP slider

Lesson Summary

Student teams are each assigned one resource (i.e., wood, gravel rocks, iron ore) to focus on during engineering solution generation. Teams then analyze cross-sectional maps of four different sites on Andoddin that show the distribution of resources in order to choose which site would be best to extract their assigned resource from. After learning about the materials available for resource extraction tool design and their costs, students individually generate multiple possible design solutions.

Background

Teacher Background

For the past three lessons, students have been in the Problem section of the engineering design process, which includes the steps define (the problem) and learn (about the problem). In this lesson, students shift to the Solution section of the engineering process, which includes: plan (the solution), try (the plan of the solution), test (the solution), and decide (whether the solution successfully solves the problem). Students will not complete all Solution steps in order to choose which site to extract their assigned resource from. They will simply examine the cross-sections of the maps provided, choose a site, and justify their choice. However, for the design of the resource extraction tool, students will complete all steps in the Solution section of the engineering design process. In this lesson, students will individually start developing written plans for their resource extraction tool prototype. For more information about the engineering design process presented in this unit, see the front matter section about it.

The four Andoddin Site Maps provided for this lesson represent a cross-section of each site. As such, they do not show all of the estimated amount of resources available at the site. In order to translate from the amount visible on the cross-sectional maps to the real amount available in the site, multiply the amount of resources available by three. This will work exactly for the trees, and it will provide a decent estimate for gravel rocks and iron ore. This is also useful to remember when making the sites and explaining the maps to students. These sites are supposed to be fairly uniform across the width of the plastic bin, while the cross-sectional maps show their variance along the length and height of the bin. This means that the resources should be placed in approximately straight lines across the width of the bin. For example, the three trees needed for Site 2 should be placed in a fairly straight line near one end of the bin; this is represented by one tree in *4.d. Andoddin Site 2 Map.*

Label the left and right sides of the bin according to the site maps to make it easier to construct the sites and locate resources.

Before the Activity

Create one site as an example to teach students how the cross-sectional site maps correspond to the three-dimensional site in real life. It is recommended to create the site represented by the *4.e. Andoddin Site 3 Map* duplication master. See the Educator Resource *4.a. Andoddin Site Instructions* for a guide about how to make the sites.

Site Selection & Tool Design Idea Generation

LESSON 4

If using the duplication masters, print and make copies of the following worksheets in the labeled amounts:

- *4.c. Andoddin Site 1 Map* (1 per team)
- *4.d. Andoddin Site 2 Map* (1 per team)
- *4.e. Andoddin Site 3 Map* (1 per team)
- *4.f. Andoddin Site 4 Map* (1 per team)
- *4.g. Extraction Site Choice* (1 per student)
- *4.h. NWRM Additional Design Information* (1 per student)
- *4.i. Materials Cost Sheet* (1 per student)
- *4.j. Design Ideas – Individual Plan* (1 per student)

If students are writing question prompts directly into their engineering notebooks, it is still recommended to make copies in the specified amounts for: 4.c., 4.d., 4.e., 4.f., 4.h., and 4.i.

Set out the materials that students can purchase for their design. While they will not start trying/constructing during this lesson, it is helpful for them to see what materials are available and in what sizes in order to adequately plan a design solution. Most of the materials available are already in the appropriate size.

- Each piece of 5”x5” mesh will need to be cut into 2.5”x2.5” squares.
- It may be helpful to cut one 6” piece of string and masking tape so that students can see how much material that is. However, since students are not using the materials in this lesson, multiple pieces do not yet need to be cut.

Andoddin Site Clean-up Instructions (for after the activity):

- You may complete the clean up yourself, or have the students help.
- Remove the trees from the site. If they have not been taken apart, you may use them to build sites in later lessons. You may reuse the parts to assemble the trees if they are not too damaged.
- Use a magnet to remove the steel washers from the sand.
- Use a 5”x5” mesh with large holes to separate the gravel rocks from the sand. Place these in a bag to use in later lessons.
- Use the 5”x5” mesh with small holes to separate the aquarium rocks from the sand. Put them in a bag for use in later lessons.
- Dump the sand in a bag to save for use in later lessons.

NOTE: You may not need to clean up the site you used in this lesson. If it was not disrupted, you may leave it assembled for lesson 6.

Classroom Instruction

Introduction

1. **(Optional) Read the daily memo from NWRM.** Read the daily memo, *4.b. NWRM Lesson 4 Memo,* out loud to the students, highlighting the objective for that day’s mission and the focus question.

2. **Tie to the engineering design problem. Say/Ask:** *We have been working as engineers in this unit. So far, we have focused on the engineering problem, but today you will begin to think about designing a solution to the engineering problem. Can anyone tell me what our engineering problem is?* Take student answers. If needed, remind

Standards Addressed

- Next Generation Science Standards: 4-ESS3-1, *MS-ESS3-1, 3-5-ETS1-2
- Common Core State Standards – Mathematics: 4.MD.A.2

Key Terms

- Primary: design, prototype
- Secondary: cross-sectional map

Assessments

Pre-Activity Assessment
Check students’ ability to explain the engineering problem and identify where they are in the engineering design process. Students should be able to move the paper clip on their sliders to the appropriate step.

Activity Embedded Assessment
Check the student teams’ discussions and written justifications for why they chose the sites that they did based on the resource they were assigned.

Post-Activity Assessment
Check the students’ initial design ideas and justifications to see if they make sense within the context of the problem.

DUPLICATION MASTERS

- 4.c. Andoddin Site 1 Map
- 4.d. Andoddin Site 2 Map
- 4.e. Andoddin Site 3 Map
- 4.f. Andoddin Site 4 Map
- 4.g. Extraction Site Choice
- 4.h. NWRM Additional Design Information
- 4.i. Materials Cost Sheet
- 4.j. Design Ideas – Individual Plan

EDUCATOR RESOURCES

- 4.a. Andoddin Site Instructions
- **(Optional)** 4.b. NWRM Lesson 4 Memo

students that in addition to designing a resource extraction tool prototype, they first need to choose a site on Andoddin to use their tool.

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

Activity

Part 1: Choose a Resource Extraction Site

4. **Introduce students to the site maps.** Pass out *4.c. Andoddin Site 1 Map, 4.d. Andoddin Site 2 Map, 4.e. Andoddin Site 3 Map,* and *4.f. Andoddin Site 4 Map*, one to each team. As a whole class, use the map key to identify what each of the symbols means (i.e., surface covering, sand, iron ore, trees, gravel). Point out that all four potential resource extraction sites have sand that is covered in a layer of environmental surface covering. However, the three main resources are different in each site, both where they are in the site and how much is there. **(Optional)** You may assemble the sites in front of students, so they have a better understanding of the dimension of depth and layers of the sites.

5. **Show students one three-dimensional site.** Display one previously made site; it is recommended to use the site from *4.e. Andoddin Site 3 Map*. While students will not be able to see the gravel rocks and iron ore within the sand, they should see a total of nine trees across the top of the site, three trees in three rows. **Ask:** *How does the three-dimensional site in real life look similar to and different from the cross-sectional map you have?* Students should make several observations:
   - There are three rows of three trees, making a total of nine trees. This means the cross-sectional map does not show all of the resources; it just shows rows of them.
   - The entire surface is covered in a thin layer of the environmental surface covering.
   - From the side, the sand, surface covering, and trees are all visible, and the layers that they are in match the layers on the cross-sectional map. (A few glimpses of gravel rocks and/or iron ore might be visible in the sand, but they also might not be.)

   (Optional) Remove the trees, surface covering, and sand until the layer of gravel rocks and iron ore is exposed. Have students make additional observations.
   - There are two rows of three pieces of iron ore in the site; there are only

two pieces of iron ore represented on the cross-sectional map.
- There are most likely not exactly 12 pieces of gravel rock, but there are definitely more than four gravel rocks in a layer.
- As indicated on the map, the iron ore and gravel rock are in about the same layer of sand; however, one side of the site has the iron ore pieces, and the other side has the gravel rocks.

6. **Discuss the amount of resources at each site.** Ask students to look at a different site map. Have them explain the relationship between the "Estimated Amount of Resources" listed and the actual number of each resource shown on the cross-sectional map. They should note that each resource icon on a map represents one row of that resource, and that each row contains about three of that item. This "multiply by three" rule works exactly for trees, but it is an approximation for iron ore and gravel rocks. That is why the total amount of iron ore and gravel rocks at each site is given a range.

7. **Assign each team a resource.** This may be done somewhat randomly (e.g., drawing a slip of paper with the resource name on it from a hat), or student teams could choose which resource they want to extract. However, make sure that there is a somewhat even distribution of resource specialties across the teams. For example, if there are eight teams, there should be two resources that each have three teams and one resource with two teams.

8. **Choose a site.** Pass out one *4.g. Extraction Site Choice* to each student, or have them record the three prompts in their engineering notebooks. **Say:** *Now that you know which resource your team will design a resource extraction tool for, you need to choose one of the four sites to extract that resource from when you test your team's prototype. As a team, examine the four sites carefully before choosing a site.* Remind students that they not only need to choose a site, they also need to justify why they chose that site instead of the other ones. It may also be helpful to remind students to think not just about the total amount of their assigned resource available at each site, but also where that resource is located on the site. Give the students time to discuss their site choice as a team. Circulate during this discussion, listening and touching base with the teams. Assist any teams that may still struggle to understand how the cross-sectional maps represent the real three-dimensional site. **(Optional)** When all teams are finished, have them share their assigned resource, chosen site, and reasons for choosing that site with the rest of the class.

Part 2: Individual Design

9. **Transition to the design. Say:** *Now that your teams have chosen a site from which to extract your resource, you can begin to think about your design for the resource extraction tool prototype.*

10. **Introduce the term "design." Say:** *We have used the term "design" a lot in this unit. So far, we have used it as something we do; we are going to design a solution. However, "design" can also refer to an object*

in engineering. In this case, a design is a written plan and/or drawing that shows how the engineering problem is solved. The solution to the problem is usually a design. Today you will begin planning your designs, which means that you will start thinking about and writing down ideas for your resource extraction tool prototype.

11. **Review the engineering problem. Ask:** *What are the criteria and constraints of the engineering problem?* If students are having trouble remembering, remind them to look at: *1.b. NWRM Client Letter,* the questions for the client along with the answers, and/or the questions they answered during lesson one on the *1.d. Define the Problem* worksheet or in their engineering notebooks.

12. **Introduce more about the engineering problem.** Pass out *4.h. NWRM Additional Design Information*, one to each student. **Say:** *Our client, Micah Bergmann from New World Resource Management, has contacted me with some updates about the engineering problem. You already know some of this information, but some of it may be new.* Review the information, emphasizing any new information. NOTE: Depending on what questions the students thought to ask the client during lesson one, various amounts of this information will be new to them. There may be additional design features that came up during lesson one that are not represented in *4.h. NWRM Additional Design Information* (e.g., tool prototype size, manufacturability/ ease of creation). Feel free to add these to *4.h. NWRM Additional Design Information* or remind students about them in some other way.

13. **Introduce the cost sheet.** Point out that one of the constraints of the problem is that the prototype should cost less than $12.00, but students don't yet know how much each material costs. Pass out a *4.i. Materials Cost Sheet* to each student. **Say:** *You will need to use this cost sheet to calculate the cost of your team design. If your design costs more than $12.00, then it does not meet the requirements, or constraints, that the client asked for. You do not need to fill it out when you are brainstorming new design ideas now, but use it as a reference to estimate how cheap or expensive your ideas are.* NOTE: For this initial idea generation activity, students do not actually need to fill out *4.i. Materials Cost Sheet* for each idea they have, but they should use it as a reference.

14. **Individual plan.** Either pass out *4.j. Design Ideas – Individual Plan* to students or have them copy a similar template into their engineering notebooks. **Say:** *First, we are going to create some plans on our own. I want to give each of you a chance to come up with your own ideas before you meet as a team and decide on one design that you will describe and justify in more detail. To be the most creative and make sure that you don't get stuck on one idea, I want each of you to come up with at least three designs. Instruct students to draw and explain their three ideas on the 4.j. Design Ideas - Individual Plan worksheet* (or similar version drawn in their engineering notebooks). Point out that for these initial designs, the "Why do you think this will work?" could include evidence from the previous science lessons, cost, and other justifications. NOTE: If students find the spaces

available for sketching their design ideas constricting, encourage them to draw on other pages of their engineering notebooks. If they choose to do this, make sure they are still sketching and explaining why they think each design idea will work.

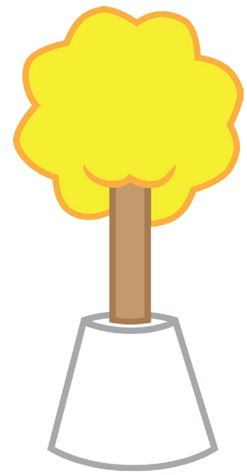
Closure

15. **Review the engineering problem. Say/Ask:** *Our client asked us to do two main tasks as part of the engineering problem. What were those tasks? How did we work on them today?* Take student answers. Tell students that their task in choosing a site from which to extract resources was completed in this lesson, but they will continue to work on designing a resource extraction tool prototype for several lessons to come.

4.a. Andoddin Site Instructions (1/4)

Trees: (see diagram at right)

1. If necessary, cut the ¼" diameter dowel rods into sticks 2" long.
2. Place one small dot of hot glue onto one end of a 2" long dowel rod. Quickly push a 1" pom-pom onto the glue.
3. Place one small dot of hot glue onto the other end of the dowel rod. Place the flat bottom of an upside-down 1-oz. plastic cup to the glue.



NOTE: Be careful not to use too much glue. Part of the challenge for students is to separate the trunks (dowel rods) from the leaves (pom-poms) and roots (1-oz. plastic cups), and this becomes difficult if a lot of glue is used. You may also use tacky glue or PVC to make the pom-poms easier to remove.

Gravel Rocks: Use a spare 1-oz. cup as a scoop.

Iron Ore: When placing each steel washer, lay it flat on the sand. (The *Andoddin Site Maps* show the iron ore pieces sideways, but that is just so they're easy to see.)

NOTE: While the instructions below say to use iron ore in rows of three, this is slightly adjustable depending on how many steel washers are available. A couple fewer or more pieces is acceptable as long as the total number of pieces stays within the range stated on each of the *Andoddin Site Maps.*

Creating the sites: (see Andoddin Site Maps for reference)

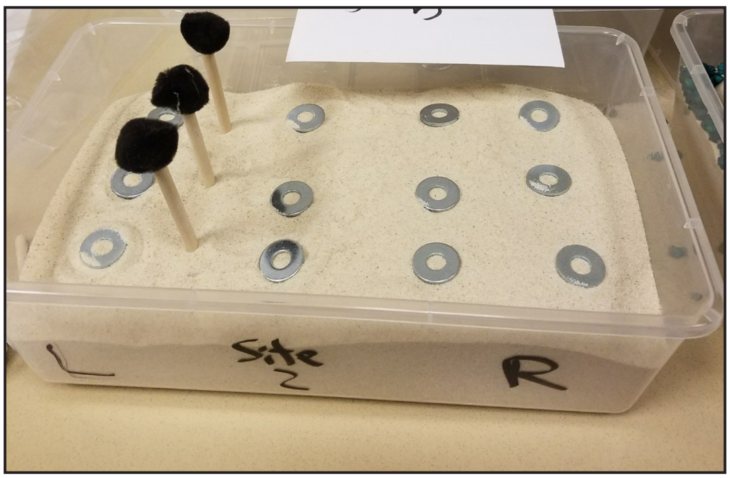
Site 1 (9 trees, 3 scoops of gravel rock):

1. Pour a 1" thick layer of sand into a plastic bin.
2. Scatter one scoop of gravel rocks over the left half of the sand layer and another scoop of gravel rocks over the right half of the same sand layer. (There should be a little space in the middle between the two scoops.)
3. Pour another 1" thick layer of sand.
4. Scatter one scoop of gravel rocks over the right half of this sand layer.
5. Place 9 trees, in three rows of three trees, in the left half of the bin. These trees should be close together, in total not taking up more than half of bin.
6. Pour another 1" thick layer of sand. This layer should bury the trees' roots in the sand, leaving only the trunks and leaves above the sand.
7. Cover the remaining sand (including any spaces between the trees) with a thin layer of aquarium rocks. The goal is to leave very little (if any) sand visible through the layer while keeping the layer of aquarium rocks as thin as possible.

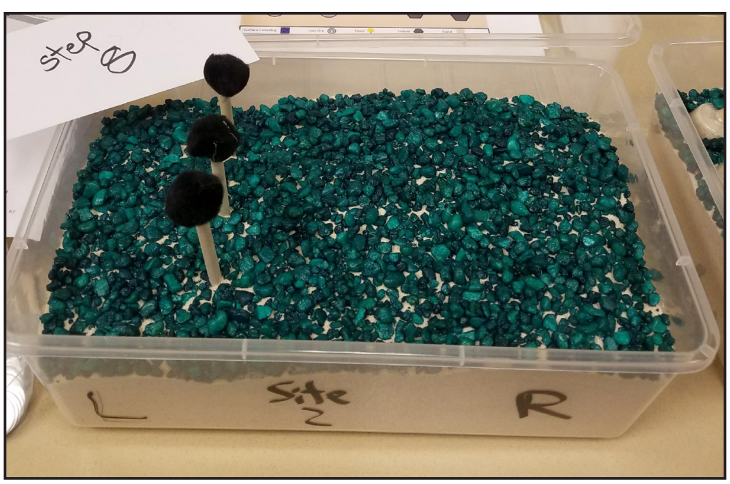
4.a. Andoddin Site Instructions (2/4)

Site 2 (3 trees, 16-20 pieces of iron ore, 1 scoop of gravel rock):

1. Pour a 1” thick layer of sand into a plastic bin.
2. In the left half, place 6 pieces of iron ore in two rows of three pieces.
3. In the right half, scatter one scoop of gravel rocks across the width of the bin.
4. Place 3 trees, in one row of three trees, in the left half of the bin.
5. Pour another 1” thick layer of sand. The trees’ roots should be covered in the sand, leaving only the trunks and leaves above the sand.
6. In the left half, place 6 pieces of iron ore in two rows of three pieces. Place another 2 rows of three pieces of iron ore on the right half of the sand layer (pictured below).



7. Pour another 1” thick layer of sand.
8. Cover the remaining sand (including any spaces between the trees) with a thin layer of aquarium rocks. The goal is to leave very little (if any) sand visible through the layer while keeping the layer of aquarium rocks as thin as possible (pictured below).



4.a. Andoddin Site Instructions (3/4)

Site 3 (9 trees, 6 pieces of iron ore, 1 scoop of gravel rock):

1. Pour a 2” thick layer of sand into a plastic bin.
2. In the left half, scatter one scoop of gravel rocks across the width of the bin.
3. In the right half, place 6 pieces of iron ore in two rows of three pieces (pictured below).

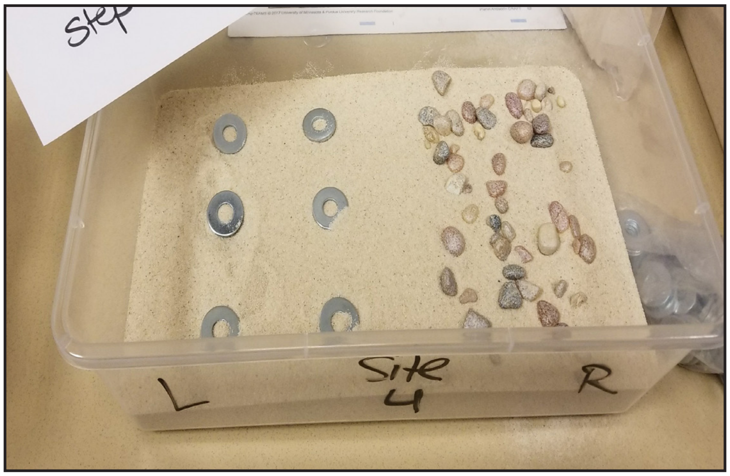
4. Pour another 1” thick layer of sand.
5. Place 9 trees, in three rows of three trees, over the top of the whole sand layer. These trees should be fairly spread out and don’t need to be exactly in rows.
6. Pour another 1” thick layer of sand. The trees’ roots should be covered by the sand, leaving only the trunks and leaves above the sand.
7. Cover the remaining sand (including any spaces between the trees) with a thin layer of aquarium rocks. The goal is to leave very little (if any) sand visible through the layer while keeping the layer of aquarium rocks as thin as possible.

LESSON 4

4.a. Andoddin Site Instructions (4/4)

Site 4 (12-16 pieces of iron ore, 3 scoops of gravel rock):

1. Pour a 1” thick layer of sand into a plastic bin.
2. In the left half, place 6 pieces of iron ore in two rows of three pieces.
3. In the right half, scatter one scoop of gravel rocks across the width of the bin (pictured below).



4. Pour another 1” thick layer of sand.
5. In the left half, scatter two scoops of gravel rocks across the width of the bin.
6. In the right half, place 9 pieces of iron ore in three rows of three pieces (pictured below).

7. Pour another 1” thick layer of sand.
8. Cover the sand with a thin layer of aquarium rocks. The goal is to leave very little (if any) sand visible through the layer while keeping the layer of aquarium rocks as thin as possible.

4.b. NWRM Lesson 4 Memo

NWRM New World Resource Management

Dear Student Engineers,

Congratulations on learning important information about natural resources and environmental impact! This will be useful as you begin thinking about solutions to the engineering design problem. Each resource extraction team will be assigned one resource to become an expert in removing from Andoddin. These resources are wood, iron ore, and gravel rocks. We need your team to do two important tasks.

First, we have located several sites on Andoddin that have been scanned with a long-range sensor and mapped. We need each team to analyze the data from the scans and choose one site to extract their assigned resource from. You will need to justify your site choice.

Second, each student engineer should generate at least three different design ideas for the resource extraction tool. This tool needs to remove your team's assigned resource from Andoddin while being mindful of the impact the tool has on the surface environment of the planet.

Focus Question: What is the best site for mining resources?

Mission Objective: Identify a suitable site for resource extraction.

Sincerely,

Micah Bergmann

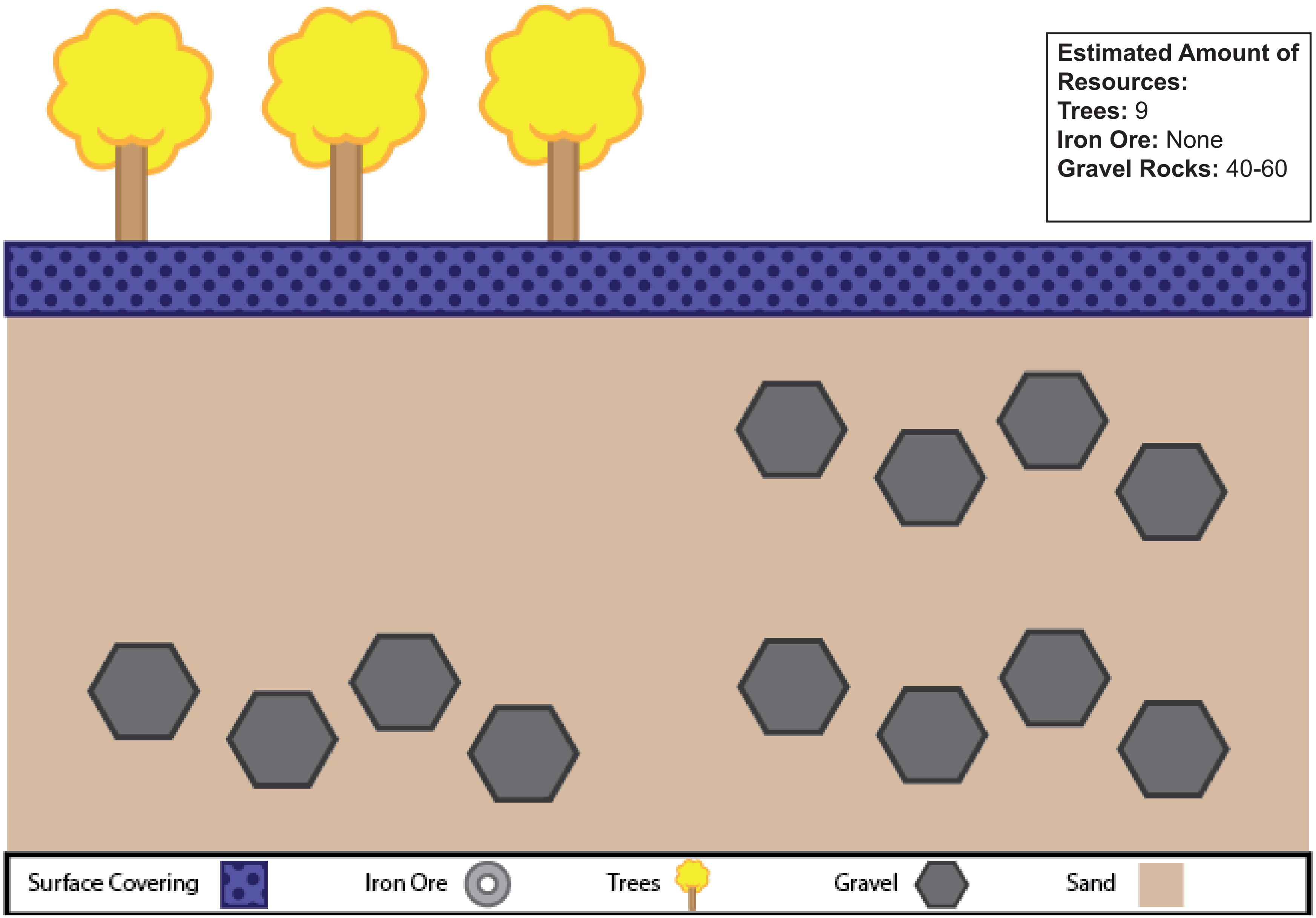
Micah Bergmann, President
New World Resource Management

LESSON 4

Name______________________________ Date____________ Period _____

4.c. Andoddin Site 1 Map

Estimated Amount of Resources:
Trees: 9
Iron Ore: None
Gravel Rocks: 40-60

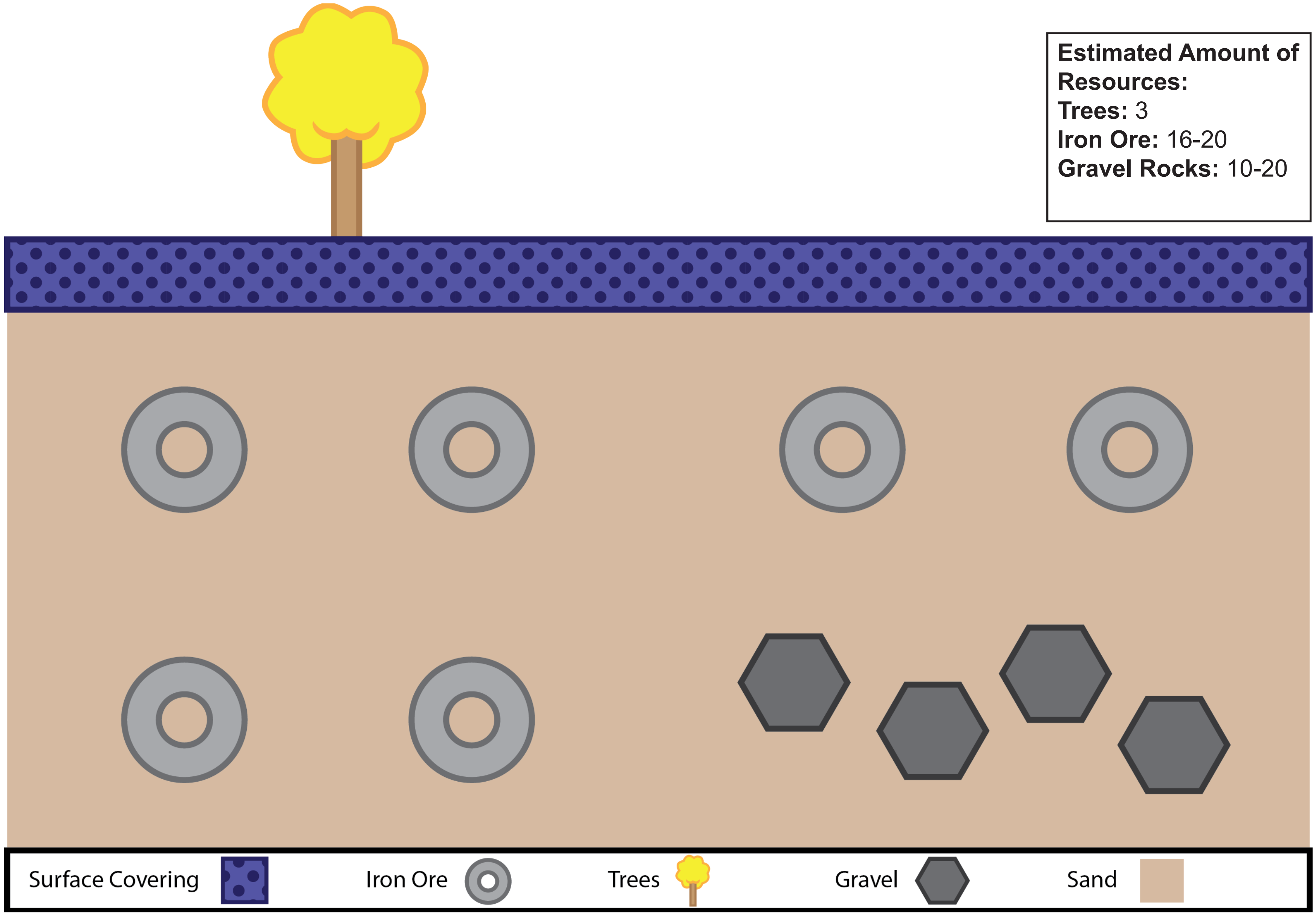


LESSON 4

Name________________________________ Date____________ Period _____

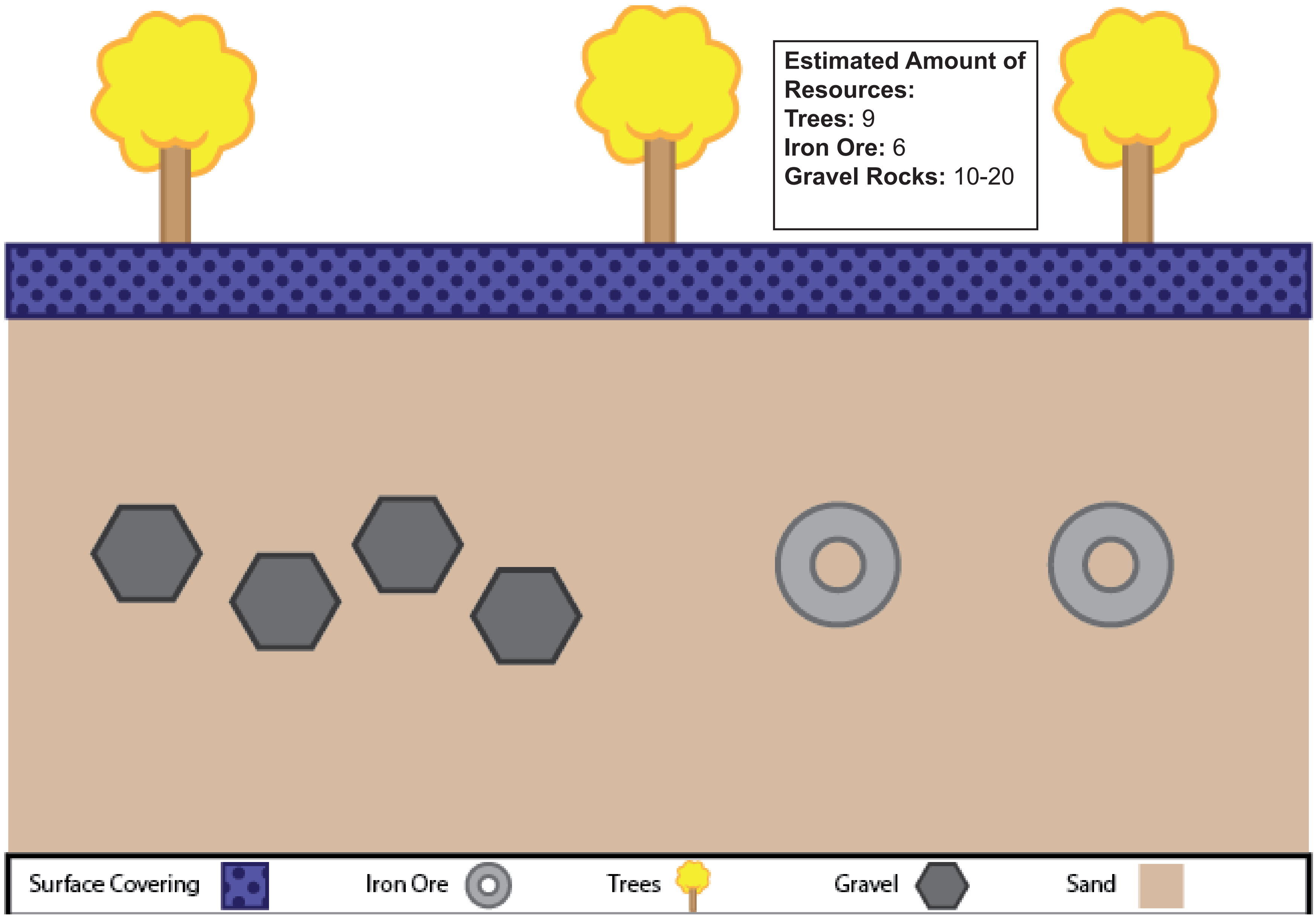
4.d. Andoddin Site 2 Map

Estimated Amount of Resources:
Trees: 3
Iron Ore: 16-20
Gravel Rocks: 10-20



Name________________________ Date__________ Period _____

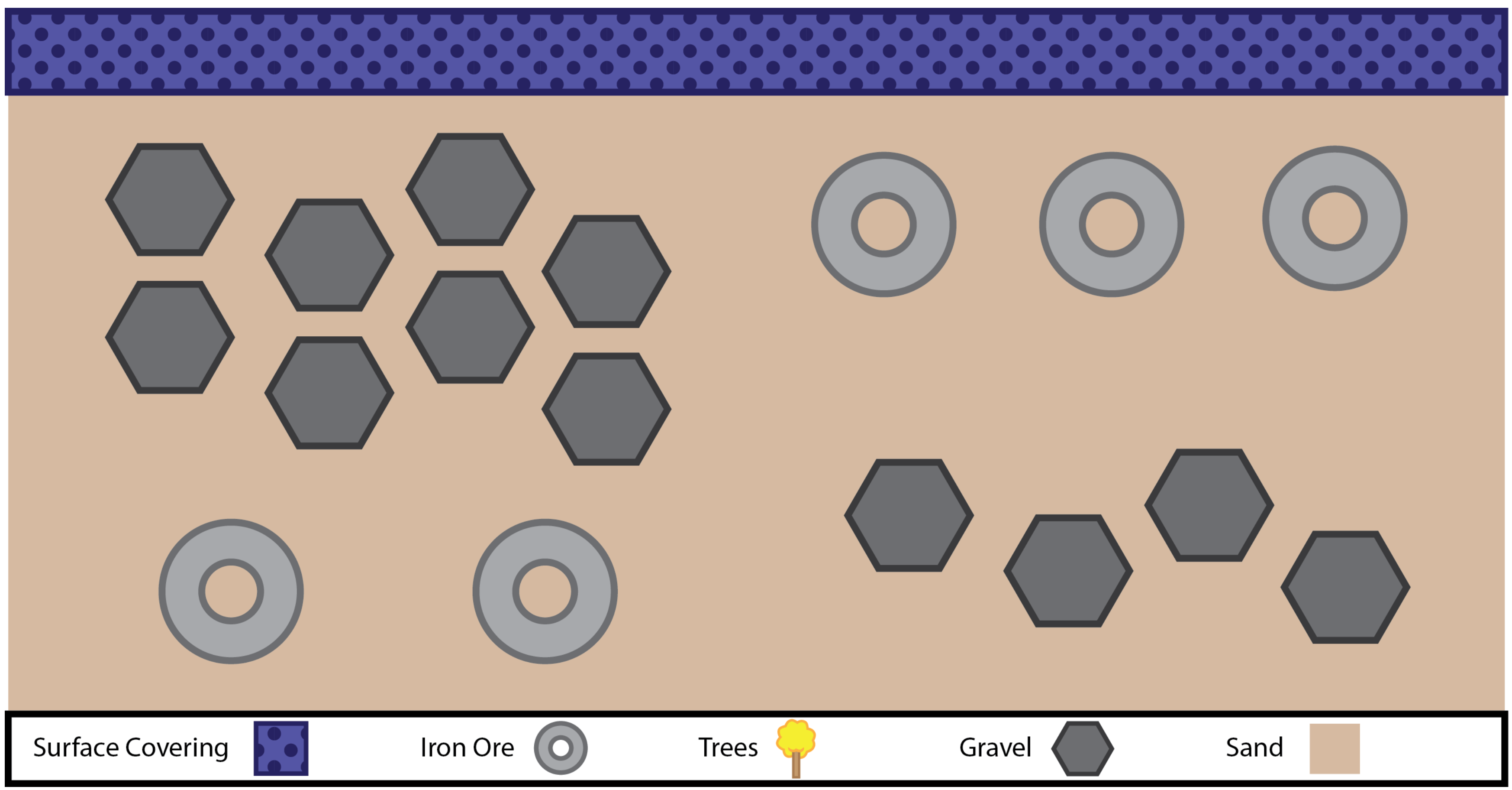
4.e. Andoddin Site 3 Map



Name_______________________ Date__________ Period _____

4.f. Andoddin Site 4 Map

Estimated Amount of Resources:
Trees: 0
Iron Ore: 12-16
Gravel Rocks: 40-60



LESSON 4

Name________________________________ Date__________ Period _____

4.g. Extraction Site Choice

1. Which resource is your team assigned to extract? ________________

2. Which site on Andoddin does your team want to extract from? _______

3. Justify your site choice. Why did you choose this site instead of the others?

LESSON 4

Name________________________________ Date__________ Period _____

4.g. Extraction Site Choice

1. Which resource is your team assigned to extract? ________________

2. Which site on Andoddin does your team want to extract from? _______

3. Justify your site choice. Why did you choose this site instead of the others?

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Name________________________________ Date____________ Period _____

4.h. NWRM Additional Design Information

NWRM New World Resource Management

Dear Student Engineers,

We have additional information about the engineering design challenge.

Goal: Design a tool prototype that extracts your team's specific resource from the exoplanet Andoddin.

- Extract a lot of your assigned resource.
- Disrupt the surface environment as little as possible.
- Keep the tool design cheaper than $12. Less money spent is better.

Specific Resource Requirements:

- Wood: The tool must remove the roots and leaves of the trees; we only want the trunks. While extracting the trees, leave the roots in the ground.
- Gravel rocks: The tool must separate the large gravel rocks from all other materials on Andoddin.
- Iron ore: The tool must separate the iron ore from all other materials on Andoddin.

Other details:

- You may build more than one tool if necessary, but your total cost is the materials you need for both tools.
- You may only use the materials on the Materials Cost Sheet.
- You will use your chosen site model to test your tool prototype.
- You will have 10 minutes to use your tool prototype during the test.
- Your hands (or other body parts) of any team member may not be used as part of the tool, and may not be used to remove any material from the resource site!

Sincerely,

Micah Bergmann

Micah Bergmann, President
New World Resource Management

Name________________________ Date____________ Period ______

4.i. Materials Cost Sheet

Material	Cost per Item	X Number of Items	= Total Item Cost
Toothpick (1)	$1.00		
Craft Stick (1)	$1.50		
Paper Clip (1)	$1.50		
Pipe Cleaner (1)	$3.00		
Bamboo Skewer (1)	$2.00		
Paper Cup (1)	$4.50		
Mesh Screen (2.5”x2.5”)	$3.50		
Magnet (1)	$5.00		
4”x6” Notecard (1)	$2.00		
Rubber Band (1)	$1.50		
String (6”)	$4.00		
Masking Tape (6”)	$5.00		
		Total Materials Cost:	

LESSON 4

Name________________________________ Date___________ Period _____

4.j. Design Ideas – Individual Plan

Design Idea	Why do you think this will work?
#1	
#2	
#3	

LESSON 5

Tool Design Selection & Evidence-Based Reasoning

Lesson Objectives

Students will be able to:

- systematically evaluate various solutions based on the problem to narrow to one design solution.
- justify why their proposed design solution is appropriate based on the application of core science/mathematics concepts, and information obtained in problem scoping.
- add and multiply decimals to calculate the cost of the design, keeping the cost under $12.00.

Time Required

one 50-minute class period

Materials

Per classroom:

- EDP poster
- materials available for design:
  - toothpicks
  - craft sticks
  - paper clips
  - pipe cleaners
  - bamboo skewers
  - 3 oz. paper cups
  - mesh screens (2.5"x2.5")
  - magnets
  - 4"x6" notecards
  - rubber bands
  - string
  - masking tape
- resources for students to see:
  - a few pieces of gravel rocks
  - a few pieces of iron ore (steel washers)
  - a few assembled trees
- (1) poster-sized sheet of sticky note paper
- markers

Per student:

- (2) different colors or types of writing utensils
- engineering notebook
- 1 EDP slider

Key Terms

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

Lesson Summary

Students review what information they have learned about the engineering problem and use it to continue solution generation. They use a list of materials and their cost, as well as what they have learned about natural resources, resource extraction, and environmental impact, to design a tool for mining their team's assigned resource from their chosen site. In the previous lesson, students generated multiple possible design solutions individually. In this lesson, they meet as a team and use the ideas generated individually to determine one design solution that will be implemented and tested. Students use evidence-based reasoning to justify their proposed design solution.

Background

Teacher Background

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

Before the Activity

On one poster-size sheet of sticky note paper, draw an Evidence-Based Reasoning template (like Worksheet 5.b.). This poster will contain explanations of the terms on the worksheet and what kind of information goes in each section. An example of this poster is included in the Duplication Masters section of this lesson. Students are not to copy this version into their *5.d. Evidence-Based Reasoning* worksheets. Rather, they are to use it as a guide to help them fill out their own versions of the template. **(Optional)** This poster can be created in advance of the lesson instead of filling it out as the lesson goes along. However, leave space on the poster for additional information if students make suggestions that are not already present.

If using the duplication masters, print and make copies of the following worksheets in the labeled amounts:

- *5.b. Selecting a Design Idea* (1 per student)
- *5.d. Evidence-Based Reasoning* (1 per student)

Also, it may be helpful to make extra copies of *4.i. Materials Cost Sheet* (see lesson 4) in case students already wrote on it during the previous lesson.

Set out the materials that students can purchase for their design. While they will not start trying/constructing during this lesson, it is helpful for them to see what

Tool Design Selection & Evidence-Based Reasoning

materials are available and in what sizes in order to adequately plan a design solution. Most of the materials available are already in the appropriate size.

- The mesh will need to be cut into 2.5"x2.5" squares.
- It may be helpful to cut one 6" piece of string and masking tape so that students can see how much material that is. However, since students are not using the materials in this lesson, multiple pieces do not yet need to be cut.

Also, have a few examples of each resource available for students to look at (i.e., a few each of gravel rocks, iron ore, and trees) so they can have a better understanding of how their tool should work. Students can look at, measure, and feel these objects, but they should not be testing the resources (e.g., attempting to remove the leaves [pom-pom] and roots [1-oz. cups] from the tree trunk [dowel rod]).

Classroom Instruction

Introduction

1. **(Optional) Read the daily memo from NWRM.** Read the daily memo, *5.a. NWRM Lesson 5 Memo*, out loud to the students, highlighting the objective for that day's mission and the focus question.

2. **Tie to the engineering problem. Say/Ask:** *Later today, we are going to review all of the details of the engineering problem. For now, can anyone tell me a short version of what our engineering problem is?* Take student answers.

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

4. **Discuss the importance of planning. Ask:** *Why do you think it is important for engineers to plan and create written designs before they create, test, and evaluate the designs?* Take student guesses. Guide discussion so students realize that creating/building designs to test and evaluate (whether they are objects or processes) can be expensive, use a lot of materials, and take a lot of time, so engineers work hard and spend a lot of time on written plans first.

Activity

5. **Select a design solution.** Refer students to their *4.j. Design Idea - Individual Plan.* Pass out *5.b. Selecting a Design Idea*, one to each student, or have students write the first prompt into their engineering notebooks. Prompt students to answer the first question, "*What are the pros and cons of each of your solutions?*" **Say:** *As you review your designs, write down the pros and cons of each of the solution ideas. As you think about developing one design solution, remember that you can choose one design idea or use the best parts from multiple design ideas.* Have students get into teams and discuss their resource extraction tool design ideas and what materials they could use.

Standards Addressed

- Next Generation Science
- Standards: 4-ESS3-1, *MS-ESS3-1, 3-5-ETS1-2
- Common Core State Standards – Mathematics: 4.MD.A.2

Assessments

Pre-Activity Assessment
Check students' ability to explain the engineering problem, including the criteria and constraints, as well as identify where they are in the engineering design process. Students should be able to move the paper clip on their sliders to the appropriate step.

Activity Embedded Assessment
Check students' progressive understanding through their verbal and written responses when deciding upon a design idea and filling out *5.d. Evidence-Based Reasoning* template. This is especially important because students will need to use information from each of the four previous lessons in this activity.

Post-Activity Assessment
Check the student teams' design ideas and justifications to see if they make sense within the context of the problem. Assess student responses to the *5.b. Selecting a Design Idea* worksheet and *5.d. Evidence-Based Reasoning* graphics with the corresponding rubrics (*5.c.* and *5.e.*, respectively)

DUPLICATION MASTERS

- 5.b. Selecting a Design Idea
- 5.d. Evidence-Based Reasoning

EDUCATOR RESOURCES

- **(Optional)** 5.a. NWRM Lesson 5 Memo
- 5.c. Selecting a Design Idea Rubric
- 5.e. Evidence-Based Reasoning Rubric
- 5.f. Evidence-Based Reasoning Instructions

6. **Introduce evidence-based reasoning.** Post an evidence-based reasoning template drawn on a sheet of poster size sticky note paper. Pass out a *5.d. Evidence-Based Reasoning* graphic to each student or have them draw the EBR template in their notebooks. **Say:** *To help you continue planning your design, we are going to be using evidence-based reasoning. This means that you will need to support your design ideas with evidence and explanations. We will discuss each of the parts together.* Clarify with students that the *5.f. Evidence-Based Reasoning Instructions* poster will have general explanations and reminders of what kind of information should go in each section. This is different from what the students will write in the templates. They will fill out the boxes with information specific to their engineering design problem.

7. **Review the problem.** Direct students' attention to the "Problem Including Criteria and Constraints" section of the *5.d. Evidence-Based Reasoning* worksheet and posters. On the poster, write down a general definition of "problem" (i.e., the problem the client asked you to solve). Instruct students to write a summary of their engineering problem in this section, leaving room for criteria and constraints.

8. **Review the criteria and constraints of the problem. Ask:** *Can anyone remind me what the words "criteria" and "constraints" mean?* Criteria are the requirements, or goals, of the designed solutions. Constraints are things that limit design possibilities. Write these definitions on the Evidence-Based Reasoning poster. Refer students back to their lists of criteria and constraints from their *1.d. Define the Problem* notes, as well as any additional information provided in *4.h. NWRM Additional Design Information.* **Ask:** What are some of the criteria and constraints of our engineering problem? Discuss the criteria and constraints of the problem, and have students write them in the "Problem including Criteria and Constraints" section of the *5.d. Evidence-Based Reasoning* graphic. NOTE: Use this time to show students the resources they will be extracting (pieces of gravel and iron ore and assembled trees). Remind students that their tools need to remove as many of these resources from the planet as possible in 10 minutes.

9. **Remind students about the cost sheet.** Point out that one of the constraints of the problem is that the prototype should cost less than $12.00. Remind students to use *4.i. Materials Cost Sheet* as a reference when they are discussing possible design ideas in their team. Tell them that they need to fill out the cost sheet once they have decided on one design.

10. **Introduce the concept of simplifying assumptions. Say:** *Engineers usually don't deal with every single aspect of a problem at once, otherwise, it becomes too difficult to solve. Instead, they make a complex problem simpler, sometimes by ignoring some of the details of the problem and sometimes by pretending certain things are true about the problem when they actually aren't.* Write "ways to make a complex problem simpler" in the "Simplifying Assumptions (if any)" section of the *Evidence-Based Reasoning* poster. **Ask:** *What are some parts of our engineering problem that we can*

make simpler? This may be a difficult concept for students, so provide an example or two if students struggle.

- Simplifying assumptions (things to ignore): aesthetics/appearance, durability (how well it withstands wear and damage).
- Simplifying assumptions (assume certain things are true when they aren't): materials used in classroom are household materials similar to those the company has.

11. **Explain what information goes in each of the remaining sections.** Have students guess at what kind of information they think should go in the "Plan," "Data/Evidence," and "Explanation, Justification, Reasoning" sections of the *5.d. Evidence-Based Reasoning* graphic. Write down relevant student suggestions in the appropriate section of the *Evidence-Based Reasoning* poster. This could include:
    - **Design Idea:** Description of the design idea; drawings of the design idea, possibly with different views (e.g., top view, side view); dimensions/sizes; label materials in the design idea to show where they are used; interesting features of the design idea.
    - **Data/Evidence:** Observations and data that show why you think your design will work. Examples: data from the Cookie Mining lab; total cost of the design.
    - **Justification:** Complete sentences that state why you think your design will be successful. These sentences should refer to the problem, criteria, constraints, idea, and data/evidence.

12. **Complete evidence-based reasoning.** When student teams have figured out what their design solution is, have them fill out *4.i. Materials Cost Sheet*, as well as the rest of their *5.d. Evidence-Based Reasoning* worksheet or template in their notebook with their team's design. Circulate during these discussions, listening and touching base with the teams. Ask why they would choose certain materials or ways of putting them together. Refer them to the other data they have already collected about good tools. NOTE: While each student in a team will fill out the same information about their team's design solution, each student does need to complete the evidence-based reasoning template. Remind students to think about the information they wrote in the "Problem including Criteria and Constraints" and "Simplifying Assumptions" sections when they justify their chosen design solution. If students find the space available for sketching their design solution constricting, encourage them to draw in other pages of their engineering notebooks.

Closure

13. **Reflect upon design solution.** Direct students' attention to the second prompt on *5.b. Selecting a Design Idea* worksheet (or written in their engineering notebooks). **Say:** *Now that your team has decided upon one design, explain why you chose that design.* Circulate and check students' rationale, making sure it makes sense in the context of the engineering problem.

5.a. NWRM Lesson 5 Memo

NWRM New World Resource Management

Dear Student Engineers,

Thank you for choosing extraction sites for each resource. You will use models of these sites to test your extraction tool prototypes, so you need to keep your site choice in mind when you design your tool.

Each of you also should have come up with several ideas for your team's resource extraction tool. Now you need to discuss these ideas with your resource extraction team and decide on one design. This design does not have to be one team member's design. Your team can combine the best ideas from many team members' designs. Remember that your goal is to create a tool that will extract your team's assigned resource while doing little damage to the surface of Andoddin.

When your team has decided on a tool design, you will need to explain your idea and why you think it will work in the Evidence-Based Reasoning graphic and also list your materials on the Materials Cost Sheet. Please include as much information as possible so we understand your idea.

Focus Question: How can we remove natural resources without damaging the environment?

Mission Objective: Design a tool that removes resources from a test site.

Sincerely,

Micah Bergmann

Micah Bergmann, President
New World Resource Management

LESSON 5

Name________________________________ Date___________ Period _____

5.b. Selecting a Design Idea

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

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

LESSON 5

Name________________________________ Date___________ Period _____

5.b. Selecting a Design Idea

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

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

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Student Name________________________ Date__________ Period _____

5.c. Selecting a Design Idea Rubric

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

Notes:

Name________________________________ Date___________ Period _____

5.d. Evidence-Based Reasoning (1/2)

Problem with Criteria & Constraints

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

Problem: ____

____

Criteria: ____

Constraints: ____

Simplifying Assumptions

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

____

____

Design Idea #____ • Plan including drawing, labels of materials used, and labels of what each part does.	**Data/Evidence** • List science/mathematics learned and/or results of tests that support your design idea.

LESSON 5

Name______________________________ Date____________ Period _____

5.d. Evidence-Based Reasoning (2/2)

Justification - Why do you think this design idea will work?

- Explain how your data and evidence support your design idea in order to meet criteria/constraints.

Student Name______________________________ Date__________ Period _____

5.e. Evidence-Based Reasoning Rubric

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

5.f. Evidence Based Reasoning Instructions

Poster with Explanation

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

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

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

Constraints: **things that limit design possibilities**

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

Ways to make a complex problem simpler.

Design Idea #____ • Plan including drawing, labels of materials used, and labels of what each part does.	**Data/Evidence** • List science/mathematics learned and/or results of tests that support your design idea.
• **Drawings of the design, different views** • **Dimensions (sizes)** • **Description of the design - labels of how different parts function** • **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 science and mathematics lessons, labs, and activities** • **Theoretical science/mathematics that provide reasons for choices they made** • **Total cost of design**

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

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

5.f. Evidence Based Reasoning Instructions

Planet Andoddin Example

Problem with Criteria & Constraints

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

Problem: Choose an Andoddin site that will be best to extract resources from and design tools that the workers can use to extract the resources.

Criteria: The tool needs to extract as many resources as possible and do little damage to the surface.

Constraints: We can only use the materials on the list and our prototype should only cost $12.00.

Simplifying Assumptions

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

Ignore appearance and durability, the company has the materials being used

Design Idea #____	Data/Evidence
• Plan including drawing, labels of materials used, and labels of what each part does.	• List science/mathematics learned and/or results of tests that support your design idea.
• Student plans will vary. See EBR poster for the type of information students should include in their plan.	• Student responses will vary. See EBR poster for the type of information students should include in their data/evidence.

Justification - Why do you think this design idea will work?

- Explain how your data and evidence support your design idea in order to meet criteria/constraints.

Student responses will vary. See EBR poster for the type of information students should include in their explanation.

LESSON 6

Try a Solution

Lesson Objectives

Students will be able to:

- implement a design and create a prototype resource extraction tool.
- add and multiply decimals to calculate the cost of the design, keeping the cost under $12.00.

Time Required

one 50-minute class period

Materials

Per classroom:

- EDP poster
- materials available for design:
  - toothpicks
  - craft sticks
  - paper clips
  - pipe cleaners
  - bamboo skewers
  - 3 oz. paper cups
  - mesh screens (2.5"x2.5")
  - magnets
  - 4"x6" notecards
  - rubber bands
  - string
  - masking tape
- resources for students to see:
  - a few pieces of gravel rocks
  - a few pieces of iron ore (steel washers)
  - a few assembled trees

Per team:

- scissors
- (1) ruler

Per student:

- (2) different colors or types of writing utensils
- engineering notebook
- EDP slider

Standards Addressed

- Next Generation Science Standards: 4-ESS3-1, *MS-ESS3-1, 3-5-ETS1-2
- Common Core State Standards – Mathematics: 4.MD.A.2

Key Terms

prototype

Lesson Summary

Students implement their planned design and create a prototype resource extraction tool. Before students can obtain materials, they submit two items to the teacher for approval: a *5.d. Evidence-Based Reasoning* worksheet, explaining the team's chosen design, and a *4.i. Materials Cost Sheet* with materials chosen and cost amounts calculated. Once checked, the teacher distributes materials and offers guidance to teams if they seem to have forgotten materials.

Background

Teacher Background

Students will be using scissors to construct their resource extraction tool prototype. Reinforce with the class safety rules already in place for using scissors. Also, the toothpicks, plastic mesh screen, bamboo skewers, and paper clips available for purchase have sharp pointy edges; they should take care with these materials if they choose to purchase them.

The main role of the teacher during this lesson will be checking in on student teams and distributing materials. As such, having the materials organized before class is necessary. During the class, there are two suggested options for distributing materials. The first is to set up a Materials Distribution Center that can be a stable position from which the teacher can easily observe and monitor all students while passing out materials. The second is to gather all of the materials in a bin and move from team to team distributing materials. Choose whichever option, or create a third, that best meets the needs of the class.

This lesson is written as to not allow students to purchase additional materials once they go to the store, with the exception of tape, string, and/or rubber bands. The purpose of this is to encourage students to think deeply about and use their design plans, rather than just tinker with materials and create a tool without any planning.

Have a place ready for students to safely store their prototype tools when class is over.

Before the Activity

Print and make copies of *6.b. Teacher Observation Protocol: Try Lesson* (enough for each team to have a line on the sheet). This document will not be given to the students, but it will be needed for observations of students during the lesson.

The most essential part of this lesson is to prepare and organize the materials that students will need in order to create their prototype tools. Most of the materials available are already in the appropriate size and thus, having a package or two of each material available will likely suffice.

- The mesh will need to be cut into 2.5"x2.5" squares. It is recommended to have 2-3 pieces pre-cut and available for each team to purchase. (Teams will not likely use all of the pre-cut mesh, but it is useful to have enough ready in case it is especially preferred.)
- Tape and string may be pre-cut into 6-inch strips, or cut as teams need

it. It is up to the teacher and the space constraints of the classroom.

Have a few examples of each resource available for students to look at (i.e., a few each of gravel rocks, iron ore, and trees), so they can have a better understanding of how their tool should work. Students can look at, measure, and feel these objects, but they should not be testing the resources with the tool prototypes (e.g., attempting to remove the leaves [pom-pom] and roots [1-oz. cups] from the tree trunk [dowel rod]).

The testing sites are not needed for this lesson, since students will not yet test their prototypes. However, it may be useful to have them made. Refer to *4.a. Andoddin Site Instructions* for more information about how to create the sites. Remember to create one site for each team, whichever site they chose. For example, if three teams chose Site 1, then three plastic bins of Site 1 need to be made.

Classroom Instruction

Introduction

1. **(Optional) Read the daily memo from NWRM.** Read the daily memo, *6.a. NWRM Lesson 6 Memo*, out loud to the students, highlighting the objective for that day's mission and the focus question.

2. **Tie to the engineering challenge. Say:** *In the previous lesson, your team decided on a plan for a prototype resource extraction tool, as requested by our client, Micah Bergmann from New World Resource Management.*

3. **Identify where they are in the engineering design process. (Try)** Draw students' attention to the *Engineering Design Process* sliders. **Ask:** *What did we do yesterday?* Plan *What do you think we are going to do today?* NOTE: Clarify with students that Try means to try out their plan by creating it, not to actually try and see how well it performs. This latter step is the Test step, which will be the next lesson.

4. **Discuss the importance of creating models/prototypes. Ask:** *Why do you think it is important for engineers to create models and prototypes? Wouldn't it be easier to send our designs to the client now? Why or why not?* Take student answers. Guide discussion so students' realize that it is helpful for engineers to construct model versions of their plans, even if they are not exactly the same as the final version. These models/prototypes can be tested and evaluated to see if they work the way the engineers predict.

Activity

5. **Explain the procedures for obtaining materials.** Share the following points with students before they break up into teams to finish planning (if they have not yet) and start implementing:
   - Before a team can get materials, they need to present their completed *5.d. Evidence-Based Reasoning* worksheet describing their design solution AND one completed *4.i. Materials Cost Sheet* for that design solution to the teacher for approval. These may also be written directly

Assessments

Pre-Activity Assessment
Check students' ability to identify where they are in the engineering design process. Student should be able to move the paper clip on their sliders to the appropriate step.

Activity Embedded Assessment
Check students' progressive understanding through their discussions, materials choices, and design features as they build their resource extraction tool prototypes. Go to each team assess their progress with the *6.b. Teacher Observation Protocol.* Note which teams are discussing how to maximize the amount of resources their tool will extract while minimizing the amount of environmental impact. Look for teams that seem to be adapting their design as they build. Ask them to explain their decisions.

Post-Activity Assessment
During the closure activity when students are sharing at least one feature of their resource extraction tool prototype they believe will make it successful, ask them why they think that. The purpose is to get students to justify their design solution.

EDUCATOR RESOURCES

- **(Optional)** 6.a. NWRM Lesson 6 Memo
- 6.b. Teacher Observation Protocol: Try Lesson

in students' engineering notebooks and shown to the teacher for approval.
- Once a team has purchased materials, they will not be allowed to go to the store again, except to purchase more tape, string, and rubber bands. The teams should be creating what they have decided upon in their plans, so they should have all of the materials they might need.

(Optional) Team members could be assigned roles for this trying (building) portion of the engineering design process. These roles could include a Materials Manager, a Recorder, Builders, etc. Assigned team roles would help ensure that all team members are able to contribute, keep team members on task, and help the team stay organized.

6. **Try/Build/Create.** Instruct students to start working. If needed, they can finish discussing their plan and filling out the *5.d. Evidence-Based Reasoning* sheet and *4.i. Materials Cost Sheet* for that team design either on the worksheets or directly into their engineering notebooks. Otherwise, they may bring their two worksheets up for teacher approval and receive supplies. As teams are working, walk around to each team and assess their progress with the *6.b. Teacher Observation Protocol: Try Lesson*. The observation protocol also has optional questions you may ask to further draw out students' reasoning. NOTE: Circulate between teams as much as possible (when not distributing supplies). Ask students to verbally justify their material choices and design features. Answer questions as they arise.
   (Optional) If a team finishes building well in advance of the other teams, have them make a list of design features that they think will help their model be the most successful and be prepared to explain why to the class.

7. **Clean up.** Leave enough time for students to put their tool materials neatly away and clean up the room.

Closure

8. **Share designs.** Invite teams that have finished their resource extraction tool prototypes to present them to the class and explain the design features they think will make their model successful.

Try a Solution

6.a. NWRM Lesson 6 Memo

NWRM New World Resource Management

Dear Student Engineers,

We are excited to hear that your resource extraction teams have decided upon tool prototype designs! Now you will try out your plan by building it.

Before you can create your resource extraction tool prototype, your team must present its design plan to your teacher for approval. This plan should have two pieces. First, you should have all of the materials you need listed on the Materials Cost Sheet with the total calculated cost. Second, you should have a detailed description of the engineering problem, your team's design, and evidence and explanation about why you think this design will work on the Evidence-Based Reasoning template. Please label drawings of your design plan with materials you want to use and what size you think each piece might be.

Once your design has been approved, please follow any instructions from your teacher about how to gather your materials and build your extraction tool prototype safely.

Focus Question: How can we remove natural resources without damaging the environment?

Mission Objective: Build a tool that removes resources from a test site.

Sincerely,

Micah Bergmann

Micah Bergmann, President
New World Resource Management

6.b. Teacher Observation Protocol: Try Lesson

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

Optional Question Prompts:

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

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

LESSON 7 Test a Solution

Lesson Objectives

Students will be able to:

- test their resource extraction tool prototypes.
- convert improper fractions into mixed numbers to determine how many units of resource their tool prototype extracted.
- determine the total area affected by the environmental impact of resource extraction by counting unit squares of disrupted ground cover.

Time Required

one 50-minute class period

Materials

Per classroom:

- EDP poster
- **(optional)** clear tape

Per team:

- (1) prepared site, which includes:
  - (1) medium plastic tub
  - approx. 10 lbs. sand
  - large gravel (~3/4")
  - steel washers
  - trees (each is one 1" pom-pom, one 2"x¼" dowel rod, one 1 oz. plastic cup)
  - glue gun and glue
  - aquarium rocks
- (1) overhead transparency with cm^2 grid copied
- (1) overhead or dry erase marker

Per student:

- (2) different colors or types of writing utensils
- engineering notebook
- EDP slider

Standards Addressed

- Next Generation Science Standards: 4-ESS3-1, *MS-ESS3-1, 3-5-ETS1-3
- Common Core State Standards – Mathematics: 3.MD.C.6, 3.MC.C.7.D, 3.NF.A.3.B, 4.NF.B.3.B

Key Terms

improper fraction, mixed number

Lesson Summary

Students test their resource extraction tool prototype by using it to extract their assigned resource from the Andoddin site they chose in Lesson 4. After 10 minutes of extraction, they measure how many resources their tool prototype has extracted. Also, they use a grid to measure approximately how much environmental impact their tool prototype had on the surface of Andoddin. The focus of this testing lesson is to gather data about the performance of the tool prototype.

Background

Teacher Background

An improper fraction is one in which the numerator (i.e., top number) is greater than or equal to the denominator (i.e., bottom number) and therefore are fractions greater than one. Examples of this include 4/3 and 10/4. A mixed number is one consisting of an integer and a proper fraction. For the previous two examples, their mixed number form would be 1-1/3 and 2-2/4. (The second number could also be simplified to 5/2 or 2-1/2. Simplifying fractions may be done by students during this lesson, but it is not required.) During this lesson, students will be converting the raw number of material resources they extract into the number of shipping container units they filled. In order to do this, they will first need to write an improper fraction in which the numerator is the total number of resources they extracted, and the denominator is the number of that resource that fits into a shipping container unit. They then convert this improper fraction into a mixed number. One method of doing this is outlined in the duplication master *7.c. Test Results*; however, other methods for guiding students through this process (e.g., drawing each container with extracted resource inside) could be used instead. Students often think of fractions as parts of a whole and struggle when improper fractions are introduced as there are now too many parts for a single whole. It is sometimes helpful to think of a fraction such as 4/3 as "4 pieces each 1/3 in size" or "4 times 1/3" rather than "4 out of 3 parts." If students are struggling with the outlined procedure, they could draw a picture. For example, if the fraction is 21/6, they could draw 21 symbols to represent the 21 pieces each 1/6 in size. They could then put them in teams of 3 teams of 6 to determine the whole number part and view the remaining 3 pieces as 3/6 (or 1/2).

Students will also be measuring irregular areas in order to determine the amount of environmental impact done to the surface of Andoddin by their tool prototype during resource extraction. Irregular areas can be measured by estimating what fraction of each square is covered by the irregular area. However, this is advanced for many upper elementary students. Therefore, in this curricular unit, the students count all squares that have any portion of the irregular shape covering them. (In other words, it doesn't matter if the square is covered ~25% or ~75%, it still counts.) This yields an overestimate of the area of environment damaged, but it is procedurally easier to do with students. (The directions for this are on *7.c. Test Results*.) Additionally, student teams may end up with a grid paper that has several irregular area shapes on it. In this case, students will need to add up the squares covered by each irregular area in order to determine the total area damaged. If students come up with a more accurate way to measure area, value that contribution but state that everyone should use the same strategy to maintain fairness.

Before the Activity

Create one site for each team, whichever sites each team chose in Lesson 4. If multiple teams have chosen the same site, try to make the sites as similar as possible. See the Educator Resource *4.a. Andoddin Site Instructions* for a guide about how to make the sites. Additional information about the layout of each site can be found in the cross-sectional site maps: *4.c. Andoddin Site 1 Map*, *4.d. Andoddin Site 2 Map*, *4.e. Andoddin Site 3 Map*, and *4.f. Andoddin Site 4 Map*. **(Optional)** If students will take the sites back to their desks for testing, it may be helpful to have large cafeteria-type trays underneath the sites in order to catch any site materials (e.g., sand, aquarium gravel) that may spill out. If the sites are kept in one area of the room during testing, it may be helpful to lay down a tarp or garbage bags to serve the same purpose.

If using the duplication masters, print and make copies of the following worksheets in the labeled amounts:

- *7.b. Teacher Observation Protocol: Test Lesson* (enough for each team to have a line on the sheet)
- *7.c. Test Results* (1 per student)
- *7.d. Think About Results* (1 per student)

If students are writing question prompts directly into their engineering notebooks, it is still recommended to make copies in the specified amounts for 7.b. and 7.c.

Print the square centimeter grid sheet. Copy the square centimeter grid sheet onto overhead transparency sheets, at least one transparency sheet per team. These transparency sheets may be cleaned and re-used for each class. **(Optional)** The square centimeter grid should ideally cover the surface of each site. If the 8.5”x11” transparency is too small, make a few extra copies of the centimeter grid transparencies. Then, cut up these extra grids as needed and use clear tape to tape the pieces to the main transparency grid for each team. In this way, assemble one transparency grid for each team that covers the whole surface of the site.

Additionally, the square centimeter grid can be used as a measurement tool only. Students will not need to replicate the exact position of each disrupted area, just accurately record all areas on the square centimeter grid so that they fit onto a single sheet. Students can then count the number of squares.

Have a timer ready and set to 10 minutes, or use a clock to watch 10 minutes pass during testing.

Classroom Instruction

Introduction

1. **(Optional) Read the daily memo from NWRM.** Read the daily memo, *7.a. NWRM Lesson 7 Memo*, out loud to the students, highlighting the objective for that day’s mission and the focus question.

Assessments

Pre-Activity Assessment
Check students’ ability to identify where they are in the engineering design process. Students should be able to move the paper clip on their sliders to the appropriate step.

Activity Embedded Assessment
Walk around to each team and assess their progress, using the *7.b. Teacher Observation Protocol: Test Lesson.* Check students’ mathematics when measuring the amount of environmental impact (i.e., measuring irregular areas) and converting the total number of resources extracted to number of shipping container units (i.e., converting improper fractions to mixed numbers). (This will be done on *7.c. Test Results* or in their engineering notebooks.)

Post-Activity Assessment
Check students’ understanding during the discussion analyzing the results of the tests. Most importantly, check their ability to suggest improvements to their design based on the science (i.e., resources, environmental impact) and mathematics they have learned. Provide feedback to students on their *7.d.* worksheet using the *7.e.Think About Results Rubric*.

DUPLICATION MASTERS

- 7.c. Test Results
- 7.d. Think About Results
- Square centimeter grid sheet

EDUCATOR RESOURCES

- **(Optional)** 7.a. NWRM Lesson 7 Memo
- 7.b. Teacher Observation Protocol: Test Lesson
- 7.e. Think About Results Rubric

Test a Solution

2. **Tie to the engineering challenge. Say:** *Throughout this unit, we have been designing solutions that aim to solve an engineering problem. What is that problem?*

3. **Identify where they are in the engineering design process. (Test)** Draw students' attention to the Engineering Design Process sliders. **Ask:** *What did we do in the previous class?* Try **Ask:** *What do you think we are going to do today?*

4. **Discuss the importance of testing. Ask:** *Why do you think it is important for engineers to test their models and prototypes?* Take student answers. Guide discussion so students' realize that engineers test models and prototypes to see if they work the way the engineers predict.

Activity

5. **Retrieve tool prototypes.** Have student teams get their built resource extraction tool prototypes.

6. **Have student teams get near the testing sites.** This can be done in one of two ways: pass out one site to each team (the site they chose in lesson 4), or have all of the sites located in one spot of the classroom and have teams go to their chosen site. It may be easier to clean up any spilled site materials (e.g., sand, aquarium rocks) if the sites are all near the same spot in the classroom; however, it then may be more crowded since all the teams will be in the same location.

7. **Walk students through the testing procedures.** Pass out the *7.c. Test Results* worksheet if students are using worksheets. Otherwise, they will write their testing data questions and answers directly into their engineering notebooks. Before actually performing the resource extraction test, go over the directions with the students.
   - They will have 10 minutes to use their tool prototype on their team's chosen Andoddin site.
   - They want to extract a lot of their assigned resource.
   - They need to disrupt the surface environment as little as possible.
   - Follow their Specific Resource Requirements for extraction. (These are from *4.h. NWRM Additional Design Information*.)
     i. Wood: The tool must remove the roots and leaves of the trees; NWRM only wants the trunks.
     ii. Gravel rocks: The tool must separate the large gravel rocks from all other materials on Andoddin.
     iii. Iron ore: The tool must separate the iron ore from all other materials on Andoddin.
   - **Reminder:** The hands (or other body parts) of any team member may **not** be used as part of the tool, and may **not** be used to remove any material from the resource site!

9. **Extract resources.** Using a timer or a clock, give the students 10 minutes to extract resources from their chosen Andoddin sites using their resource extraction tool prototype. As students are testing, circulate to make sure

they are following testing directions correctly. Also, assess student progress using *7.b. Teacher Observation Protocol: Test Lesson*. NOTE: In the first design test, some teams may determine very quickly that their tool prototype does not work. Teachers should have a classroom management strategy ready for students who are unable to proceed for the full 10 minutes of testing. Depending on teams' choice of designs, teachers may choose to shorten the test time.

10. **Pass out transparencies and markers.** Pass out one transparency sheet with centimeter squared grid on it to each team, along with an overhead or dry erase marker. These will be used to measure the environmental impact that their resource extraction tool prototypes had.

11. **Walk students through measuring environmental impact.** Read through the directions for measuring the amount of environmental impact on *7.c. Test Results*. It may be helpful to demonstrate the process. NOTE: It may be helpful to tell students that they do not have to be perfect here. Their tracings should be close, but they will likely not be exact. Similarly, they do not have to perfectly follow the lines when coloring in the squares that touch the tracing shapes. The purpose of coloring in the squares is to make it easier for students to count the squares in order to measure the environmental impact. **(Optional)** In order for students to be able to reach and draw on the transparency as it is being held above the site, it may be helpful to move the site to the floor instead of on a table or desk. This would make it easier for a short student to see a bird's-eye view of the site.

12. **Measure and record environmental impact.** Direct the student teams to measure the environmental impact of their resource extraction tool prototype and then record their final result. Circulate the room and assist as needed. **(Optional)** Teachers may also take a picture of the mining site surface with the grid overlaid, and use it as a visual when measuring environmental impact. NOTE: If student teams have multiple tracings on their grid sheet (i.e., not just one blob), make sure they add up the squares from all of the tracings to get the total amount of environmental impact.

13. **Count the number of resources extracted**. Have students count the number of resources they fully extracted according to their Specific Resource Requirements (as outline by *4.h. NWRM Additional Design Information*.) NOTE: A resource that was extracted from the site but not separated properly (i.e., remove the roots and leaves of trees from the trunks, separate gravel rocks and iron ore from other Andoddin materials) does NOT count toward the team's number of resources extracted.

14. **Record the number of resources extracted.** Have students record the number and circle the type of resource extracted on *7.c. Test Results*.

15. **Go over the instructions for converting resources.** Read through the directions about converting the number of resources extracted to number

of shipping container units on *7.c. Test Results*. NOTE: The instructions on *7.c. Test Results* of converting improper fractions into mixed numbers are only one possibility for how students could do this conversion. Feel free to use another method if appropriate.

16. **Convert the resources and record.** Have student teams convert their number of resources extracted to number of shipping container units extracted. Team number of resources may or may not be an improper fraction. Circulate among the teams and assist as needed. NOTE: It may be helpful for students to draw each shipping container unit and the number of resources they extracted inside each one. This can be done on a separate page in their engineering notebooks. For student teams extracting iron ore or gravel rocks, they may end up with an improper fraction and mixed number that can be simplified. (For example, 6/4 or 1 2/4 can be simplified to 1 1/2.) The team can choose to do this; however, it is not required for this unit.

17. **Summarize results.** Once teams have measuring and converting data from their resource extraction test, have them rewrite their final results in the "Summary of Results" section of *7.c. Test Results*. This includes the cost of materials used in their prototype (which they can get from that design's *4.i. Materials Cost Sheet*) and any additional features of their design that they think are advantageous. For example, an additional criterion may have emerged (e.g., keep the tool size small for easier transport to Andoddin) when asking questions of the client in lesson 1. How well their prototype meets these additional criteria should be addressed in "Additional features of your design."

Closure

18. **Go over results analysis.** Pass out *7.d. Think About Results*, or have students record those questions in their engineering notebooks. Have students read through the questions.

19. **Think about results individually.** Give students time to reflect on their testing results individually. They should write their answers in the "My response" section.

20. **Think about results as a team.** Have students meet in their teams and discuss their answers. When the team has decided upon a response, have them record this in the "Team response" section using a different writing utensil.

21. **Clean up.** If necessary, have students sweep up any sand, aquarium rocks, resources, or other site supplies and dump them back into the site. The sites can be reused, so it is better to keep all supplies than throw them away. Refer to the "Before the Activity" section in lesson 4 for how to clean up the sites. Have students put away their resource extraction tool prototypes and sites. Students can also use a tissue or paper towel to clean off their overhead transparency sheet and return it.

Lesson 7
Test a Solution

LESSON 7

7.a. NWRM Lesson 7 Memo

NWRM New World Resource Management

Dear Student Engineers,

Congratulations! Your engineering teams have done a great job planning and building a resource extraction tool prototype. The next step is to test your prototypes to see how well they work.

You will test your extraction tool prototype on a model of the site your team chose. Your goal is to remove as many of your team's assigned resources from the site as possible during the set time. However, you also want to impact as little of the environmental surface covering of Andoddin as possible.

It is very important to collect data about how well your team's tool prototype works during this practice extraction mission. Please carefully follow your teacher's instructions about how to measure the number of resources extracted and the amount of environmental impact done on the surface. You will need to analyze these data later, so make sure you carefully record data during this test.

Focus Question: How can we remove natural resources without damaging the environment?

Mission Objective: Test a tool that removes resources from a test site.

Sincerely,

Micah Bergmann

Micah Bergmann, President
New World Resource Management

7.b. Teacher Observation Protocol: Test Lesson

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

Optional Question Prompts:

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

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

Name________________________________ Date___________ Period _____

7.c. Test Results (1/2)

How well does your resource extraction tool prototype work? Let's test it.

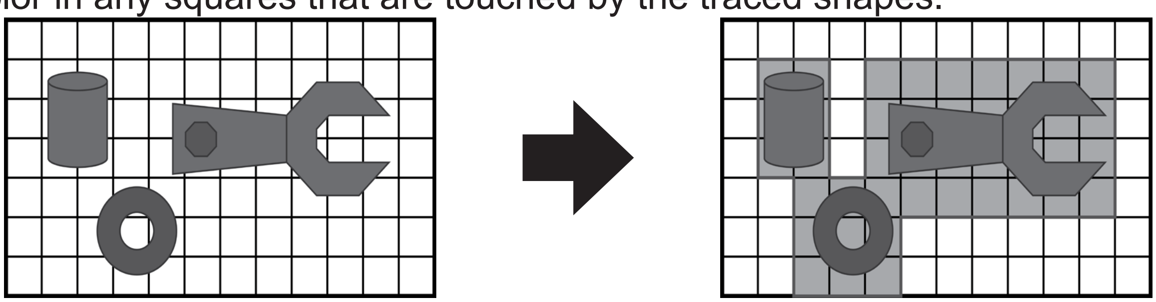
Directions for Testing:

- You will have 10 minutes to use your tool prototype on your team's chosen Andoddin site.
- Extract a lot of your assigned resource.
- Disrupt the surface environment as little as possible.
- Follow your Specific Resource Requirements for extraction.
- **Reminder:** Your hands (or other body parts) of any team member may **not** be used as part of the tool, and may **not** be used to remove any material from the resource site!

Data from Testing:

Amount of environmental impact:

1. Have one or two team members hold the grid transparency sheet over the site after testing.
2. Have another teammate use an overhead or dry erase marker to trace on the transparency where the surface covering is not there anymore. (Trace any place where you can see the sand.)
3. Place the transparency on a desk or table.
4. Color in any squares that are touched by the traced shapes.



5. Count the number of squares colored in. This is the environmental impact of your design.

Amount of environmental impact: __________ square centimeters

Number of resources extracted: __________

Circle one: Tree trunks Iron ore Gravel rocks

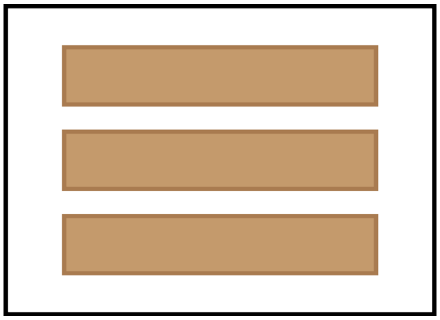
LESSON 7

Name________________________________ Date___________ Period _____

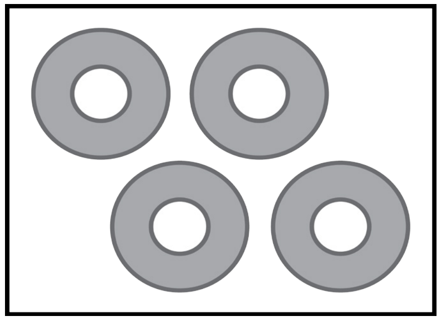
7.c. Test Results (2/2)

Convert number of resources to number of shipping container units:

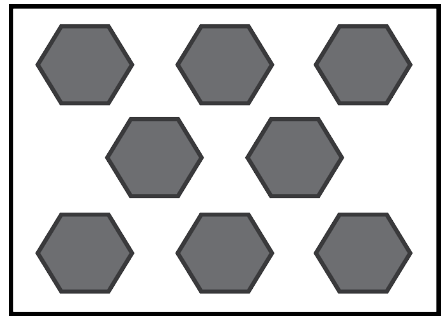
1 shipping container unit holds:



3 tree trunks



4 iron ore pieces



8 gravel rocks

Write an improper fraction that shows how many resources your team extracted compared to how many resources your shipping unit holds.

$$\frac{\text{Number of resources extracted}}{\text{Number of resources per shipping unit}} = \underline{\hspace{4cm}}$$

Convert this improper fraction into a mixed number. How many shipping container units did your team extract?

Summary of Results:

Cost of materials used: $ __________

Amount of environmental impact: __________ square centimeters

Number of full shipping container units extracted: __________ units

Partial shipping container unit? Yes No

Number of resources in partial shipping container unit: __________ units

Additional features of your design:

LESSON 7

Name_______________________________ Date___________ Period _____

7.d. Think About Results

Directions: Please answer the following questions about what you learned from testing your design.

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

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

   Team response:

3. What changes will you make to improve your solution based on the results of your tests?
   My response:

   Team response:

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

   Team response:

Student Name________________________ Date__________ Period _____

7.e. Think About Results Rubric

Problem	Question	Learning Objectives	Rubric	
7.e.1	What were the results of your test(s)?	Analyze test results.	yes no	**Listed specific results of tests**
7.e.2-4	2. What have you learned about the performance of your solution from your test results? Explain both the things that worked and did not work.	Analyze test results.	yes no	**Explained advantages of solution found in tests**
		Apply evidence gathered through test analysis to improve the performance of chosen solution.	yes no	**Explained drawbacks of solution found in tests**
	3. What changes will you make to your solution based on the results of your tests?		yes no	**Listed planned improvements**
	4. Why will you make those changes? Think about the results of your tests and the mathematics and science you have learned.	Apply evidence gathered from testing to choose solution.	yes no	**Explained rationale for improvements based on test results**
		Apply mathematics/science concepts to inform redesign.	yes no	**Explained rationale for improvements based on correct understanding of mathematics/ science**

Notes:

LESSON 8

Decide About a Solution

Lesson Objectives
Students will be able to:
- compare data about their design's performance with the performance of their peers' designs.
- complete a chart to analyze the performance of their resource extraction tool prototypes.

Time Required
One 50-minute class period

Materials
Per classroom:
- EDP poster

Per student:
- (2) different colors or types of writing utensils
- engineering notebook
- EDP slider

Standards Addressed
Next Generation Science Standards: 4-ESS3-1, *MS-ESS3-1, 3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3

Key Terms
criteria, constraints

Lesson Summary
Student teams share their resource extraction tool prototype and results with other teams assigned to the same resource. They analyze their prototype's performance data in comparison with other teams in order to determine why some designs work better than others. Students decide how well their design met each of the criteria and then begin thinking about redesign.

Background
Teacher Background
In this lesson, student teams will have discussions with other teams who were assigned the same resource about their designs and how well they worked to meet each of the criteria and constraints. The purpose of these comparisons is to help all teams think about how they can learn from each other and improve their own resource extraction tool prototype design. It is not meant to be a competition, but rather a learning experience.

The "Additional Feature" rows of the data table in *8.b. Comparing with Other Teams* are optional. The class may have decided upon an additional criterion during problem scoping (e.g., size of the prototype, how easy it is to make the prototype) that could be added here. Or, students may want to share features of their design that aren't necessarily meeting assigned criteria, but that they think make their design more advantageous to the client and/or end-user.

Before the Activity
If using the duplication masters, print and make copies of the following worksheets in the labeled amounts:
- *8.b. Comparing with Other Teams* (1 per student)
- *8.c. Decide about a Solution* (1 per student)

Classroom Instruction
Introduction
1. **(Optional) Read the daily memo from NWRM.** Read the daily memo, *8.a. NWRM Lesson 8 Memo*, out loud to the students, highlighting the objective for that day's mission and the focus question.

2. **Tie to the engineering challenge. Say:** *Throughout this unit, we have been designing solutions that aim to solve an engineering problem. What is that problem?*

3. **Identify where they are in the engineering design process. (Decide)** Draw students' attention to the Engineering Design Process sliders. **Ask:** *What did we do in the previous class?* Test **Ask:** *What do you think we are going to do today?*

4. **Discuss the importance of decide. Ask:** *Why do you think it is important for engineers to decide whether their models and prototypes are successful?* Take student answers. Guide discussion so students' realize that engineers decide whether their prototypes are successful in order to decide whether they are ready to communicate their solution to the client or whether they need to go back and try again, or redesign. It is important for engineers to learn from failures of their designs in order to make a better

design.

Activity

5. **Explain how student teams will compare their designs.** If using duplication masters, pass out *8.b. Comparing with Other Teams.* Review the directions as a whole class. Make sure students understand that they are only comparing their design with other teams who were assigned the same resource. (It would not make sense for a team that extracted iron ore to share their design and results with a team that extracted gravel rocks.) NOTE: It may help to emphasize that the purpose of these comparisons is to help all teams think about how they can learn from each other and improve their own resource extraction tool prototype design. It is not a competition, but rather a learning experience.

6. **(Optional) Make a data table.** If not using duplication masters, have students make a data table similar to the one in *8.b. Comparing with Other Teams* in their engineering notebooks. NOTE: The "Additional Feature" rows of the data table are optional. The class may have decided upon an additional criterion during problem scoping (e.g., size of the prototype, how easy it is to make the prototype) that could be added here. Or, students may want to share features of their design that aren't necessarily meeting assigned criteria, but that they think make their design more advantageous.

7. **Share data.** Have student teams get into three teams based on the resource they were assigned to extract: wood, iron ore, or gravel rocks. Each team should show their resource extraction tool prototype, explain how it works, and share their results from testing with the other teams in their team. All teams should record their own data, as well as the other teams' data, in the chart on *8.b. Comparing with Other Teams* or in their engineering notebooks.

8. **Discuss data.** After sharing their design's results, have students in the teams discuss and record answers to the questions: *How well did each design meet the criteria?* and *Why did some designs work better than others?* Circulate during these discussions, taking note of students' answers to these questions.

9. **(Optional) Share results with whole class.** Have one or two representatives from each of the three teams share the main ideas they discussed in their assigned resource team, especially how their designs were similar or different and why they thought some designs worked better than others.

10. **(Optional) Share unique aspects of the tool prototype.** As a whole class, have teams with unique "additional features" share those features with the class and why they think the client and/or end-user will find them useful.

Assessments

Pre-Activity Assessment
Check students' ability to identify where they are in the engineering design process. Students should be able to move the paper clip on their sliders to the appropriate step.

Activity Embedded Assessment
Check students' progressive understanding through their verbal and written responses when analyzing their design as compared with other teams' using *8.b. Comparing with Other Teams* (either on the worksheet or in their engineering notebooks).

Post-Activity Assessment
Check student teams' understanding during the discussion while they fill out *8.c. Decide about a Solution* (either on the worksheet or in their engineering notebooks). It is especially important that they consider all criteria and how well their design did or did not meet those criteria and constraints. provide feedback using the *8.d. Decide about a Solution Rubric.*

DUPLICATION MASTERS

- 8.b. Comparing with Other Teams
- 8.c. Decide about a Solution

EDUCATOR RESOURCES

- **(Optional)** 8.a. NWRM Lesson 8 Memo
- 8.d. Decide about a Solution Rubric

Decide About a Solution

Closure

11. Introduce decide about a solution. If using duplication masters, pass out *8.c. Decide about a Solution.* If not, have students record the question prompts into their engineering notebooks. **Say:** *We have finished testing and comparing your initial designs for the resource extraction tool prototype. Now, each team needs to decide how successful their prototype is. How well does it meet the criteria and constraints of the problem?*

12. Individually decide about a solution. Have students first individually think about and record answers to questions 1 (*In what ways does your solution meet the criteria and constraints of the problem?*) and 2 (*In what ways does your solution not yet meet the criteria and constraints of the problem?*) in the "My response" space in either in their engineering notebooks or directly on *8.c. Decide about a Solution*.

13. Team decide about a solution. Have students share their answers to questions 1 and 2 with their team. They should then discuss and record their answers using a different writing utensil under the "Team response" space.

Decide About a Solution

LESSON 8

8.a. NWRM Lesson 8 Memo

NWRM New World Resource Management

Dear Student Engineers,

We are very excited about your progress! Your teacher has informed us about your resource extraction tool prototypes and the practice extraction mission you performed. We are interested to find out the results.

Please follow your teacher's directions to analyze the data you collected from the tests. We are most interested in the overall cost of the prototypes, how many units of resources each prototype collected, and how much environmental impact the prototypes had. Other design features may also be considered, but these are the main three criteria.

We want you to think about how well your team's prototype performed overall. This will be based on the results of your data analysis, as well as comparing your team's results to other teams' results. Once you have evaluated your design, start to think about improving it so that it better solves the engineering problem.

Focus Question: How can we remove natural resources without damaging the environment?

Mission Objective: Decide about a tool that removes resources from a test site.

Sincerely,

Micah Bergmann

Micah Bergmann, President
New World Resource Management

LESSON 8

Name______________________________ Date__________ Period _____

8.b. Comparing with Other Teams

Directions:

1. Show your resource extraction tool prototype and share your results with other teams assigned to the same resource.
2. Record all teams' data in the chart below.

	Your team's design	**Another team's design**	**Another team's design**
Cost			
Amount of Resources			
Environmental Impact			
Mining Site #			
Additional Feature			

1. How well did each design meet the criteria?

2. Why did some designs work better than others?

LESSON 8

Name______________________________ Date___________ Period _____

8.c. Decide about a Solution

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

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

   Team response:

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

   Team response:

LESSON 8

Student Name______________________________ Date__________ Period _____

8.d. Decide about a Solution Rubric

Problem	Question	Learning Objectives	Rubric	
8.c.1	In what ways does your solution meet criteria and constraints of the problem?	Evaluate the alignment between their proposed solution and the problem.	yes no	**Compared their solution to specified criteria and constraints**
8.c.2	In what ways does your solution not yet meet the criteria and constraints of the problem?	Evaluate the alignment between their proposed solution and the problem.	yes no	**Contrasted their solution to specified criteria and constraints**

Notes:

LESSON 8

Student Name______________________________ Date__________ Period _____

8.d. Decide about a Solution Rubric

Problem	Question	Learning Objectives	Rubric	
8.c.1	In what ways does your solution meet criteria and constraints of the problem?	Evaluate the alignment between their proposed solution and the problem.	yes no	**Compared their solution to specified criteria and constraints**
8.c.2	In what ways does your solution not yet meet the criteria and constraints of the problem?	Evaluate the alignment between their proposed solution and the problem.	yes no	**Contrasted their solution to specified criteria and constraints**

Notes:

LESSON 9 Redesign

Lesson Objectives

Students will be able to:

- use evidence from problem scoping, core science/ mathematics concepts, and initial design test analysis to plan an improved design.
- add and multiply decimals to calculate the cost of the improved design, keeping the cost under $12.00.
- implement the design and create an improved resource extraction tool prototype.
- test the performance of the improved solution.
- determine the total area affected by the environmental impact of resource extraction by counting unit squares of disrupted ground cover.
- convert improper fractions into mixed numbers to determine how many units of resource their improved tool prototype extracted.
- compare data from their second design's performance with the performance of their initial design.
- evaluate the alignment between their proposed solution and the problem.

Time Required

two-three 50-minute class periods

Materials

Per classroom:

- EDP poster
- poster size sticky note paper with EBR template
- (1) 5"x5" piece of mesh with small holes
- materials available for design:
  - toothpicks
  - craft sticks
  - paper clips
  - pipe cleaners
  - bamboo skewers
  - 3 oz. paper cups
  - 2.5"x2.5" mesh screens with ~0.25" holes

Lesson Summary

Based on the discussion and analysis of the initial design test results, students work to improve their resource extraction tool. Students redesign, rebuild, retest and reevaluate the performance of a tool prototype. Students compare and contrast their results with the results of their initial design and decide on which design to suggest to the client as the solution to the engineering problem.

Background

Teacher Background

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

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

For redesign, students have two options as far as materials and cost. The first is to continue to work on their initial design, changing it or adding to it. If they choose this option, any additional materials they purchase will be added to the cost of their initial design. In other words, the total materials of the redesign, including the initial design plus changes, should still cost less than $12.00. The second option is to scrap the initial design's materials and start over. If students choose to do this, they use all new materials, but all of these new materials should remain under $12.00. If they choose the second option, they will need to return any reusable materials (e.g., magnets, rubber bands, uncut materials) to the store before re-purchasing new materials.

Ideally, students would be able to redesign through several cycles. If time permits, students can continue this design/ test/redesign process. However, because of the time constraint of the classroom, students will most likely get through one redesign in two to three class periods. If a team finishes the redesign cycle (plan, try, test, decide) much earlier than other teams, you may choose to let them redesign a third prototype. Another option would be to encourage that student team to start working on their letter to the client, explaining and justifying their design.

In terms of management of this lesson, there are two choices: allow each team to proceed at its own pace or keep all teams on approximately the same step at the same time. There will be less downtime for teams if they are allowed to move ahead when ready, but as a whole classroom it will be more chaotic because teams are doing different things. If all teams stay on the same step, the whole classroom will be more organized, but there is a possibility that some teams may be done early. If this happens, have teams start thinking about the communication to the client, or do any other activity that is deemed necessary for the unit.

All other Teacher Background information from lessons 4-8 applies during redesign. (For example, it may be helpful to set up a Materials Distribution Center for when students want to purchase materials.) It is recommended to go back and look through those comments as well.

Before the Activity

Create one site for each team, whichever sites each team chose in Lesson 4. If multiple teams have chosen the same site, try to make the sites as similar as possible. See the Educator Resource *4.a. Andoddin Site Instructions* for a guide about how to make the sites. Additional information about the layout of each site can be found in the cross-sectional site maps: *4.c. Andoddin Site 1 Map, 4.d. Andoddin Site 2 Map, 4.e. Andoddin Site 3 Map, and 4.f. Andoddin Site 4 Map*. **(Optional)** If students will take the sites back to their desks for testing, it may be helpful to have large cafeteria-type trays underneath the sites in order to catch any site materials (e.g., sand, aquarium gravel) that may spill out. If the sites are kept in one area of the room during testing, it may be helpful to lay down a tarp or garbage bags to serve the same purpose.

If using the duplication masters, print and make copies of the following worksheets in the labeled amounts:

- *9.b. Redesign: Evidence-Based Reasoning* (1 per team)
- *9.d. Redesign: Materials Cost Sheet* (1 per student)
- *9.e. Redesign: Test Results* (1 per student)
- *9.g. Redesign: Decide about a Solution* (1 per student)
- *9.f. Teacher Observation Protocol: Redesign Lesson* (enough for each team to be accounted for)

If students are writing question prompts directly into their engineering notebooks, it is still recommended to make copies in the specified amounts for 9.b., 9.d., 9.e, and 9.f.

Prepare and organize the materials that students will need in order to create their prototype tools. Most of the materials available are already in the

- magnets
- 4”x6” notecards
- rubber bands
- string
- masking tape

Per team:

- scissors
- (1) ruler
- (1) prepared site, which includes:
  - (1) medium plastic tub
  - approx. 10 lbs. sand
  - large gravel (~3/4”)
  - steel washers
  - trees (each is one 1” pom-pom, one 2”x¼” dowel rod, one 1 oz. plastic cup)
  - glue gun and glue
  - aquarium rocks
- (1) overhead transparency with cm^2 grid copied
- (1) overhead or dry erase marker

Per student:

- (2) different colors or types of writing utensils
- engineering notebook
- EDP slider

Standards Addressed

- Next Generation Science Standards: 4-ESS3-1, *MS-ESS3-1, 3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3
- Common Core State Standards – Mathematics: 4.MD.A.2, 3.MD.C.6, 3.MC.C.7.D, 3.NF.A.3.B, 4.NF.B.3.B

Key Terms

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

Assessments

Pre-Activity Assessment
Check students’ ability to identify where they are in the engineering design process. Students should be able to move the paper clip on their sliders appropriately.

Activity Embedded Assessment
Check students’ progressive

LESSON 9 Redesign

understanding through their verbal and written responses during activities and discussions. Examine new prototypes and ask teams to explain...

- *Does/did their new design address the design 1 issues?*
- *Will/did the construction and/or materials of design 2 make the resource extraction tool work better?*
- *Will/did you lower the cost?*

While students are testing their redesigned resource extraction tools, walk around to each team and assess their progress using the *9.f. Teacher Observation Protocol: Redesign.*

Post-Activity Assessment
Check in with students teams as they evaluate the success of their two resource extraction tool designs and decide which one to recommend to the client. Provide feedback to students on their EBR graphic using the *9.c. EBR Rubric.*

DUPLICATION MASTERS

- 9.b. Redesign: Evidence-Based Reasoning
- 9.d. Redesign: Materials Cost Sheet
- 9.e. Redesign: Test Results
- 9.g. Redesign: Decide about a Solution

EDUCATOR RESOURCES

- **(Optional)** 9.a. NWRM Lesson 9 Memo
- 9.c. Redesign: EBR Rubric
- 9.f. Teacher Observation Protocol: Redesign
- 9.h. Redesign: Decide about a Solution Rubric

appropriate size and thus having a package or two of each material available will likely suffice.

- The mesh will need to be cut into 2.5”x2.5” squares. It is recommended to have 2-3 pieces pre-cut and available for each team to purchase. (Teams will not likely use all of the pre-cut mesh, but it is useful to have enough ready in case it is especially preferred.)
- Tape and string may be pre-cut into 6-inch strips, or cut as teams need it. It is up to the teacher and the space constraints of the classroom.

Have a few examples of each resource available (i.e., a few each of gravel rocks, iron ore, and trees) for students to look at when they are planning and building so they can have a better understanding of how their tool should work. Students can look at, measure, and feel these objects, but they should not be testing the resources with the tool prototypes (e.g., attempting to remove the leaves [pom-pom] and roots [1-oz. cups] from the tree trunk [dowel rod]).

Print Square centimeter grid sheet. Copy the square centimeter grid sheet onto overhead transparency sheets, at least one transparency sheet per team. These transparency sheets may be cleaned and re-used for each class. **(Optional)** The square centimeter grid should ideally cover the surface of each site. If the 8.5”x11” transparency is too small, make a few extra copies of the centimeter grid transparencies. Then, cut up these extra grids as needed and use clear tape to tape the pieces to the main transparency grid for each team. In this way, assemble one transparency grid for each team that covers the whole surface of the site.

Have a timer ready and set to 10 minutes, or use a clock to watch 10 minutes pass during testing.

Refer to the “Before the Activity” section in lesson 4 for how to clean up the sites after the lesson is completed.

Classroom Instruction

Introduction

1. **(Optional) Read the daily memo from NWRM.** Read the daily memo, *9.a. NWRM Lesson 9 Memo*, out loud to the students, highlighting the objective for that day’s mission and the focus question.

2. **Tie to the engineering challenge.** Have students explain the engineering problem that they have been trying to solve, including its criteria and constraints, as well as any modifications they have made to the problem based on what they learned from initial prototype testing.

3. **Identify where they are in the engineering design process. (Decide)** Draw students’ attention to the Engineering Design Process poster and their Engineering Design Process sliders. **Ask:** *What did you all do in the previous class?* Decide and re-Define the problem. Point out that in addition to deciding upon the prototype resource extraction tools’ success, they also discussed the problem again and redefined it in terms of what they learned from designing a solution. **Say:** *Now, we will be doing redesign, so we will*

need to go through solution generation (plan, try, test, and decide) again to create a second, better prototype.

4. **Discuss the importance of redesign. Ask:** *Why do you think it is important for engineers to learn from their failures and try again?* Take student answers. Guide the discussion so students' realize that learning from failure is incredibly important to engineering because it allows them to test the limits of their design solutions and then make improvements. If the design solution doesn't meet the client's criteria, then they need to improve it, and even if the design does meet the criteria, they may still want to make it even better for their client.

Activity

5. **Re-introduce EBR.** Pass out one *9.b. Redesign: Evidence-Based Reasoning* sheet (or post for them to see) and one *9.d. Redesign: Materials Cost Sheet* to each student. Review what goes in each box by referencing the Evidence-Based Reasoning explanations sticky note poster created in Lesson 5. In the box marked Evidence, add "Data from prototype testing". **Say:** *Now that we have tested out initial resource extraction tool designs, we have evidence from those tests in addition to the evidence we had before.*

6. **Introduce the materials cost constraint.** Inform students that they have an option to either keep their initial design and change it, adding new materials on to their previous cost, or scrap their initial design and start over from $0.00. Either way, the second design materials' total cost should still remain under $12.00. If they choose the second option, they will need to return any reusable materials (e.g., magnets, rubber bands, uncut materials) to the store before re-purchasing new materials.

7. **Plan the redesign.** Allow student teams time to fill out the *9.b. Redesign: Evidence-Based Reasoning* sheet and *9.d. Redesign: Materials Cost Sheet* with their new plan; this information can also be recorded in their engineering notebooks. While teams are planning, circulate and check on their new designs. Ask teams to explain how their new design addresses the problems of design one, how their new design will make the tool work better to extract more resources while lowering environmental impact, what materials they chose to improve the performance of the tool, and how they lowered the cost. When a team has adequately filled out the *9.b. Redesign: Evidence-Based Reasoning sheet* and *9.d. Redesign: Materials Cost Sheet* for their new design, they may move on to try/build. NOTE: Even if teams are using their previous prototype and adding/changing it, they should make a new *9.d. Redesign: Materials Cost Sheet* that reflects the prices of the original materials plus any additional materials they purchase for the redesign. For more information about planning and evidence-based reasoning, see Lesson 5.

8. **Try/Build the redesign.** Distribute supplies to teams at request. As before, once teams have filled out their *9.d. Redesign: Materials Cost Sheet*, those are the materials they get. They need to make sure their plan

is well thought out so they have all the materials they need since they can't go back and get more as they need them (with the exception of tape, rubber bands, and string.) Circulate among the teams as they build their second resource extraction tool prototypes. Continue to ask them questions about the design, why they made the changes they did, and why they think it will improve in performance. NOTE: For more information about planning and evidence-based reasoning, see Lesson 6.

9. **Test the redesign.** Pass out the *9.e. Redesign: Test Results* worksheets, one per student. (This sheet has instructions for testing and gathering data on it.) The data collected during and after testing questions and answers may also be written directly into students' engineering notebooks. When teams are ready, each will use their tool in the Andoddin site previously chosen, to extract as much resources as possible in 10 minutes while minimizing environmental impact. Pass out one transparency sheet with centimeter square grid (from lesson 7) and one overhead or dry erase marker so that students can measure the amount of environmental impact. When testing is done, have them record the cost, amount of resources extracted (including the conversion into amount of shipping container units), area of environmental impact, and additional features in their *9.e. Redesign: Test Results* notes. NOTE: For more information about planning and evidence-based reasoning, see Lesson 9.

10. **Assess student progress.** As students are testing and evaluating their redesigned tools, walk around and assess student progress with the *9.f. Teacher Observation Protocol: Redesign*.

Closure

11. **Decide about the redesign. Say:** *Instead of comparing your second prototype to other teams' prototypes, now you will compare your second tool prototype to your first tool prototype*. Have students compare the results of the two prototype designs and consider the following questions (on the *9.g. Redesign: Decide about a Solution* worksheet or in their engineering notebooks):
    a. What worked well with your second tool? How do you know?
    b. What did not work well with your second tool? How do you know?
    c. Which of your tool prototypes would the client think is better? Explain using evidence. (Hint: Think about whether the solution meets the criteria of the problem.)

    NOTE: While students are evaluating their designs, circulate the room. Answer questions and encourage students to support their answers with data and explanations. In more complex engineering projects, it is common to choose parts of designs that performed best and combine them into an optimal design. For this level of complexity, it will probably be easier and better for students to just pick one of their designs as the better design rather than trying to combine parts of their designs.

12. **(Optional) Share recommendation to client.** Have each student team briefly share with the class which of their resource extraction tool prototypes they think the client will like better and why. Encourage them to include

aspects of Evidence-Based Reasoning: what their solution is, data/evidence to support it, and explanations connecting the data/evidence to their proposed solution. If time allows, let students ask each other questions about their designs and why they made their choices about which one was better.

9.a. NWRM Lesson 9 Memo

NWRM New World Resource Management

Dear Student Engineers,

Thank you for completing your initial design, including: plan, try (build), test, and decide about a solution. We were excited to hear about the results of the initial prototypes that your engineering teams generated!

We now ask that you improve your resource extraction tool prototypes based on what you have learned. This redesign will include all of the solution generation steps that you did for your initial design. You will need to come up with a new plan, making sure to justify your decisions about your new design. You will also need to try out this plan, either building a completely new tool prototype or changing the initial prototype. This new prototype will be tested in the model site that your team chose. Finally, you will analyze the results of the tests and compare the results of your redesign to your initial design. You can then decide which design best solves the engineering problem.

Focus Question: How can we remove natural resources without damaging the environment?

Mission Objective: Redesign a tool that removes resources from a test site.

Sincerely,

Micah Bergmann

Micah Bergmann, President
New World Resource Management

LESSON 9

Name________________________________ Date___________ Period _____

9.b. Redesign: Evidence-Based Reasoning (1/2)

Problem with Criteria & Constraints
Problem with Criteria & Constraints • Explain the client's problem that needs a solution and why it is important to solve. • List criteria and constraints you will use to decide if your solution is working.
Problem: ____________________ ____________________ **Criteria:** ____________________ **Constraints:** ____________________
Simplifying Assumptions • List things that might be important but you have decided not to worry about.
____________________ ____________________

Design Idea #____	Data/Evidence
• Plan including drawing, labels of materials used, and labels of what each part does.	• List science/mathematics learned and/or results of tests that support your design idea.
	____________________ ____________________ ____________________ ____________________ ____________________ ____________________ ____________________ ____________________ ____________________ ____________________ ____________________ ____________________ ____________________

LESSON 9

Name________________________________ Date____________ Period _____

9.b. Redesign: Evidence-Based Reasoning (2/2)

Justification - Why do you think this design idea will work?

- Explain how your data and evidence support your design idea in order to meet criteria/constraints.

Student Name________________________ Date__________ Period _____

9.c. Redesign: Evidence-Based Reasoning Rubric

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

LESSON 9

Name________________________________ Date___________ Period _____

9.d. Redesign: Materials Cost Sheet

Material	Cost per Item	X Number of Items	= Total Item Cost
Toothpick (1)	$1.00		
Craft Stick (1)	$1.50		
Paper Clip (1)	$1.50		
Pipe Cleaner (1)	$3.00		
Bamboo Skewer (1)	$2.00		
Paper Cup (1)	$4.50		
Mesh Screen (2.5”x2.5”)	$3.50		
Magnet (1)	$5.00		
4”x6” Notecard (1)	$2.00		
Rubber Band (1)	$1.50		
String (6”)	$4.00		
Masking Tape (6”)	$5.00		
		Total Materials Cost:	

Name______________________________ Date__________ Period _____

9.e. Redesign: Test Results (1/2)

How well does your resource extraction tool prototype work? Let's test it.

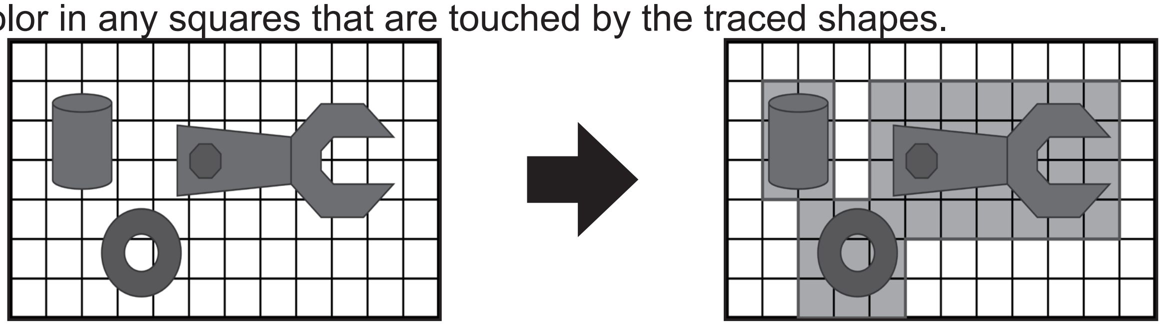
Directions for Testing:

- You will have 10 minutes to use your tool prototype on your team's chosen Andoddin site.
- Extract a lot of your assigned resource.
- Disrupt the surface environment as little as possible.
- Follow your Specific Resource Requirements for extraction.
- **Reminder:** Your hands (or other body parts) of any team member may **not** be used as part of the tool, and may **not** be used to remove any material from the resource site!

Data from Testing:

Amount of environmental impact:

1. Have one or two team members hold the grid transparency sheet over the site after testing.
2. Have another teammate use an overhead or dry erase marker to trace on the transparency where the surface covering is not there anymore. (Trace any place where you can see the sand.)
3. Place the transparency on a desk or table.
4. Color in any squares that are touched by the traced shapes.



5. Count the number of squares colored in. This is your design's environmental impact.

Amount of environmental impact: __________ square centimeters

Number of resources extracted: __________

Circle one: Tree trunks Iron ore Gravel rocks

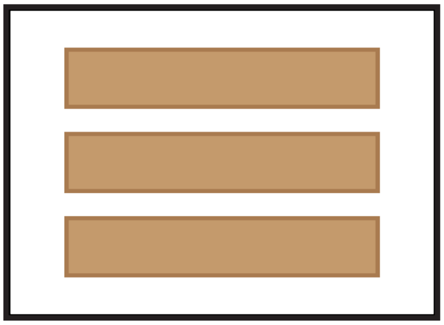
LESSON 9

Name________________________________ Date____________ Period _____

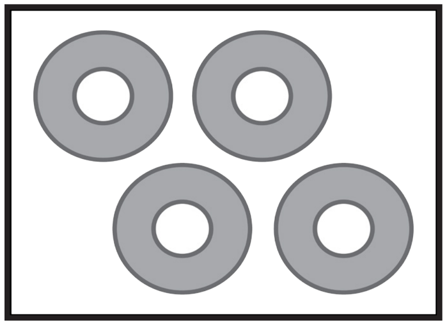
9.e. Redesign: Test Results (2/2)

Convert number of resources to number of shipping container units:

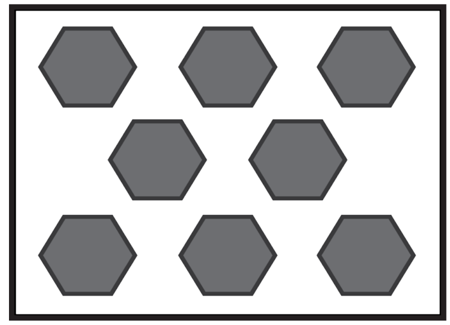
1 shipping container unit holds:



3 tree trunks



4 iron ore pieces



8 gravel rocks

Write an improper fraction that shows how many resources your team extracted compared to how many resources your shipping unit holds.

$$\frac{\text{Number of resources extracted}}{\text{Number of resources in shipping unit}} = \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_$$

Convert this improper fraction into a mixed number. How many shipping container units did your team extract?

Summary of Results:

Cost of materials used: $ __________

Amount of environmental impact: __________ square centimeters

Number of shipping container units extracted: __________ units

Additional features of your design:

9.f. Teacher Observation Protocol: Redesign Lesson

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

Optional Question Prompts:

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

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

LESSON 9

Name_______________________________ Date___________ Period _____

9.g. Redesign: Decide about a Solution

1. What are the results of your tests?
   My response:

   Team response:

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

   Team response:

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

   Team response:

Student Name__________________ Date__________ Period _____

9.h. Redesign: Decide about a Solution Rubric

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

Notes:

LESSON 10

Communicate to the Client

Lesson Objectives
Students will be able to:
- evaluate the alignment between their proposed solution and the problem.
- communicate their design solution through the use of evidence-based reasoning.
- justify why their design solution is appropriate based on application of core science/mathematics concepts, information obtained in problem scoping, and interpretation of acquired or gathered evidence.

Time Required
One 50-minute class period

Materials
Per classroom:
- EDP poster
- poster size sticky note paper with EBR template

Per team:
- If students are creating a poster, each team will need:
  - poster-sized sheet of paper
  - markers

Per student:
- (2) different colors or types of writing utensils
- engineering notebook
- EDP slider

Standards Addressed
- Next Generation Science Standards: 4-ESS3-1, *MS-ESS3-1, 3-5-ETS1-1, 3-5-ETS1-2, 3-5-ETS1-3
- Common Core State Standards – Mathematics: 4.MD.A.2

Key Terms
evidence-based reasoning, criteria, constraints

Lesson Summary
In this lesson, students write a letter to or create a poster for the client, Micah Bergmann of New World Resource Management, about their design. The letter or poster needs to explain the design with text and drawings, and justify the design with evidence and explanations.

Background
Teacher Background
The communications to the client may take the form of letters or posters, depending on what works best for the classroom. Additionally, the creation of this communication may be done by students individually or in their design teams.

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

Rubrics for evaluating and grading this communication are not included in this unit. You can create your own if you wish.

Before the Activity
If using the duplication masters, print and make copies of the following worksheets in the labeled amounts:
- **(Optional)** *9.b. Redesign: Evidence-Based Reasoning* (extra copies)
- *10.b. Reflect about Engineering Design* (1 per student)

(Optional) If there is a specific format/template for writing letters or creating posters that students need to learn and use, create this template on one sheet of poster-sized sticky note paper before the lesson starts. Students can then refer to this when considering the format of the letter or poster.

Classroom Instruction
Introduction
1. **(Optional) Read the daily memo from NWRM.** Read the daily memo, *10.a. NWRM Lesson 10 Memo*, out loud to the students, highlighting the objective for that day's mission and the focus question.

2. **Tie to the engineering challenge. Say/Ask:** *We are almost done with solving this engineering design problem! Can anyone tell me about that problem? Who was our client? What problem did they want us to solve? What were the criteria and constraints of the problem?* Take student answers.

Communicate to the Client

3. **Identify where they are in the engineering design process.** Draw student's attention to the Engineering Design Process poster and their Engineering Design Process sliders. **Ask:** *What did you do in the previous class?* Take students answers. Point out the iterative nature of the engineering design process, specifically how students went through the process twice in order to improve their solutions. Remind the students of the Communication and Teamwork piece that has arrows pointing to every step of the engineering design process. **Say:** *Throughout the entire engineering design process, we have been working in teams, and communicating within your teams and with other teams. Now you need to communicate to the client, Micah Bergmann of New World Resource Management, so that they know about your design and why it meets their needs.*

Activity

4. **Review the client letter.** Have students review the *1.b. NWRM Client Letter* that they received in Lesson 1. Emphasize the last paragraph of the letter. **Say/Ask:** *In the letter we received from Micah Bergmann of New World Resource Management, they state that they want us to communicate our designs to them. What else did they say that we need to include in our communication?* Justify the designs with evidence.

5. **Explain what needs to be included in the letter/poster.** Use the *Evidence-Based Reasoning* explanation poster to review what it means to justify a design with evidence. Instruct students to use these pieces (i.e., solution, data/evidence, explanation/reasoning/justification) in their communication to the client. Additionally, students should start their letter or poster with a review of the problem, including criteria and constraints, as well as the simplifying assumptions. If students want a blank copy of the *Evidence-Based Reasoning* worksheet to fill out to help them create their communication to the client, that is fine; however, they still need to write a letter or poster separately from the *Evidence-Based Reasoning* template. NOTE: If a specific letter or poster writing format needs to be followed, introduce that format here as well.

6. **Write the letter or poster.** Allow students plenty of time to write their letters or create their posters. Circulate the room to answer questions, help students who are struggling, and remind students that they need to include their chosen solution (with written description and drawing), evidence defending that solution, and explanations connecting the evidence to the solution in the letter or poster. NOTE: Encourage students to use information from their engineering notebooks, including all of the information from the problem scoping, science lessons and labs, and engineering design results.

Closure

7. **Reflect on the engineering design process.** Pass out *10.b. Reflect about Engineering Design*, or have the students reflect in their engineering notebooks about the entire unit, both individually and in their teams. Use the prompt on the worksheet.

Assessments

Pre-Activity Assessment
Check students' ability to identify where they are in the engineering design process. Students should be able to move the paper clip on their sliders to the appropriate step.

Activity Embedded Assessment
Check students' progressive understanding through written responses on their letter writing or poster creation activity. If students are struggling with the science or mathematics concepts or with using evidence-based reasoning to justify their design solutions with evidence, assist them. The focus of the letters/posters in this unit is that students justify their solutions with evidence and explanations. However, you may choose to assess other aspects of the letter/poster (e.g., proper letter writing format, spelling, grammar).

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. Use the *10.c. Reflect about Engineering Design Rubric* to provide feedback to students.

DUPLICATION MASTERS

- **(Optional)** 9.b. Redesign Evidence-Based Reasoning
- 10.b. Reflect about Engineering Design

EDUCATOR RESOURCES

- 5.f. EBR Instructions
- **(Optional)** 10.a. NWRM Lesson 10 Memo
- 10.c. Reflect about Engineering Design Rubric

Communicate to the Client

8. **(Optional) Share letters/posters with the client.** If time allows, have the students share their letters/posters with the rest of the class. This could be done as a whole class, with the students presenting their letters/posters to everyone, or in smaller teams, with students reading/viewing the letters/posters of others.

10.a. NWRM Lesson 10 Memo

NWRM New World Resource Management

Dear Student Engineers,

Congratulations on a successful mission! Your teams have now each created and evaluated at least two different possible solutions to the engineering problem. Each team must now choose one resource extraction tool design to communicate to us here at NWRM.

In your team's communication to NWRM, please first review the engineering problem, including the criteria and constraints. Then, describe your tool design in as much detail as possible. You will also need to justify your design with evidence and explain how your team's design is a successful solution to the engineering problem. This communication will require you to use your engineering skills, decision making skills, and science and mathematics skills in order to be successful.

You have been great employees during this process. Keep up the good work, and we look forward to seeing your communication materials!

Focus Question: How can we remove natural resources without damaging the environment?

Mission Objective: Describe and justify your design in a communication for NWRM.

Sincerely,

Micah Bergmann

Micah Bergmann, President
New World Resource Management

LESSON 10

Name________________________________ Date___________ Period _____

10.b. Reflect about Engineering Design

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

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

   My response:

   Team response:

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

   My response:

   Team response:

Student Name____________________________________ Date___________ Period _____

10.c. Reflect about Engineering Design Rubric

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

Notes:

Notebook Prompts and Titles

Teacher Directions:

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

Prompt title:
Question to answer

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

Problem Scoping Lessons - Define and Learn

Section 1:

Engineers:
What do engineers do?

Solve Problems:
How do engineers solve problems?

Section 2:

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

Section 3:

Client:
Who is the client?

Problem:

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

End-users:
Who are the end-users?

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

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

What we need to learn:
Think about the problem of extracting resources on planet Andoddin. In terms of not damaging the surface of Andoddin, what are at least 2 things you need to learn in order to design a tool successfully? Make sure to consider all important aspects of the problem. Be specific.

Notebook Prompts and Titles

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 solution ideas?

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

Test Solution Idea(s) Lessons

Section 1:

Ask students to complete after they have run their tests.

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

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

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

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

Section 2:

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

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

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

Notebook Prompts and Titles

Redesign Lessons

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

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

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

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

Final Solution Lessons

Section 1:

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

Section 2:

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

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

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

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

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

Generate Ideas/Plan Lessons