Unit 4 (Mechanisms):
Reverse Engineering

Concept

Systems are made of parts that work together.
We can figure out what makes a device work and then re-design it.

Content Objective

Student teams will reverse engineer a device and plan (on paper or in actuality) how it could be improved for certain uses.

Language Objective

Predict changes using future tense.
Contrast designs (original and improved) using 'change' prepositional phrases: *however, but, on the other hand, contrarily*, etc.
Analyze mentor text to distinguish main idea and details.
Write a summary of technical ideas in the third person for a scientifically or technically literate lay reader.

Standards

- **NGSS:**
  - **3-5-ETS1-1:** Define a simple design problem, including criteria for success and constraints on materials, time, or cost.
  - **3-5-ETS1-2:** Generate and compare multiple solutions based on criteria and constraints of the problem.

- **TEKS:**
  - **3A** Students will analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing**.**
  - **3C** draw or develop a model that represents how something works or looks that cannot be seen such as how a soda dispensing machine works.
- **ELPS:**
  - **2C** Students will learn new language structures, expressions, and basic and academic vocabulary heard during classroom instruction and interactions.
  - **3B** Students will expand and internalize initial English vocabulary by retelling simple stories and basic information represented or supported by pictures.

- **3E** Students will share information in cooperative learning interactions.
- **4I** Students will demonstrate English comprehension and expand reading skills distinguishing main ideas from details commensurate with content area needs.
- **5B** Students will write using newly acquired basic vocabulary and content-based grade-level vocabulary.

Materials

Per team of 2:

- 1 gadget per team of two students, such as a **Pez® dispenser, lipstick dispenser, spray or pump soap or lotion bottle** (clean)
- Access to tools for disassembling the gadgets, hammers, pliers, screwdrivers
- Safety goggles and protected surfaces
- Manila folders and markers
- Handouts **5.4.1-5.4.3**
- Ruler

Literature Connection

Rosie Revere Engineer by Andrea Beaty

BACKGROUND INFORMATION

What is a Mechanism?

A mechanism is a device that converts motion and force into a desired output. Mechanisms provide advantages in changing motion and force. Systems of mechanisms work together in machines. Examples of mechanisms include all of the simple machines (lever, gear, pulley, wheel and axle, screw, and inclined plane) as well as combinations of them.

What is Reverse Engineering?

Reverse engineering is a process that reinforces problem solving and invention skills. The process begins with **black box modeling** (introduced in the Level C *Beginning Lessons* book), which is inferring by the input and output what must be going on inside a device. This modeling approach helps children think logically and systematically, skills essential to all disciplines. At the conclusion of a reverse engineering exercise, we have a re-designed device. Relate this to the strategy inventors use to apply an old device in a new application or adapt it to new uses. Here are the basic steps of reverse engineering:

- PREDICTION—Looking at the device, how do you think it works and what do you think is inside? Sketch what you think and label the functions of the parts inside. This is black box modeling.
- DISASSEMBLY—Take the device apart. Use tools and safety equipment.
- EXPERIMENTATION—Find out what the parts are and their dimensions. Make a parts list and describe their functions. Infer how the parts were made.
- RE-DESIGN—Change some aspect of the device, for example, make it bigger, substitute for the original materials, add parts to adapt it for a different use, or customize it for a special client.

Benefits of Reverse-Engineered Devices

Everyday objects are not designed for everyone. Many people require adaptive devices to accomplish simple tasks. Also, though society puts a premium on "new and better!" inventions, we could be gentler on the Materials Cycle if we adapted old devices and technologies for new uses. If we use a reverse engineering attitude toward our material world, we become more active in shaping it for a better future.

Day 1: Engage *Mechanisms- Reverse Engineering*

Teacher Says/Does	Student Says/Does	Language requirements
1. **Preparation:** Collect gadgets described. Parents may be able to donate these items.		
2. Pair students up and ask what is inside of a classroom device such as a pencil sharpener or stapler. After they describe what they know and how it works to their partner, try another device. Tell them that being able to see into devices from memory or imagination helps engineers problem-solve.	In pairs, students describe what they know and how they think the device works.	There is/are _____ inside a pencil sharpener. I predict that the _____ will _____.
3. Draw a big box on the board or chart paper and ask the class to think about the box as a drawing of the outside of the pencil sharpener (or stapler). Have students help you name the parts inside and their functions. To complete this black box model, draw input action and output action. If you choose a pencil sharpener, the drawing might look like Figure 1 (p. 29) at the end of this lesson.	Students name the parts and describe their functions.	**Brick words**: rotary motion, reverse engineering, input/output, gadget.
4. Ask the class whether a person with only one working hand could operate this pencil sharpener (assuming it is rotary, two-hand operation). Let them try.	Individual students take turns turning to operate the pencil sharpener with one hand.	**Mortar words:** predict, prediction, contrast, analyze, distinguish, summary, summarize.
5. Form pairs and have students discuss the following questions: • What part of the pencil sharpener's operation would have to be changed? • How might they change it? (The rotary motion could be provided by a motor, a foot pump, or the blades could move in some other way, such as back-and-forth.).	Student pairs discuss their ideas.	I predict that there is/are _____ inside this gadget. I predict that the object moves by _____
6. Explain the exit slip (**5.4.1**).	Students complete exit slip individually.	

Day 2: Explore/Explain *Mechanisms- Reverse Engineering*

Teacher Says/Does	Student Says/Does	Language requirements
1. Tell students that reverse engineering is when you take an already made gadget and problem solve how to take it apart to re-design it to make it better. Let each team select a gadget to reverse-engineer. In teams, students should use the "Reverse Engineering" (**5.4.2**) handout to complete the process. Please be sure they wear goggles before smashing any gadgets they cannot use tools to open. 2. While the students are working, use the **Collaborative Dialogue Template** (p. 32 in Teacher Handbook) to guide conversations and take a running record of students' progress on content and language objectives. 3. When they have completed the "Reverse Engineering" have teams draw the inside of their gadget inside a manila folder and write the name of the gadget on the outside. 4. Have teams show their "black box folder" and quiz the other class members on what's inside the team's gadget, considering input and output, all of which is written inside the folder.	Students work in teams to reverse-engineer a gadget of their choice. They complete Reverse Engineering handout. Students create a "black box folder" for their gadget. Teams present their black box folder while other students guess the internal mechanisms of the gadget.	'Change' prepositional phrases: *however, but, on the other hand, contrarily*, etc.

Day 3: Elaborate *Mechanisms- Reverse Engineering*

Teacher Says/Does	Student Says/Does	Language requirements
1. Lead a brainstorming session on how students might redesign the gadget from the first lesson (the pencil sharpener or stapler). An explanation of one brainstorming method can be found at: https://dschool.stanford.edu/sandbox/groups/dstudio/wiki/2fced/attachments/660d8/Brainstorming-Method.pdf?sessionID=c3133c02388816a389bbea719d302d62bc56e651		
2. Display the questions below. Have student teams discuss them in relation to their black box gadget from Day 2. • What are other ways to adapt or re-design this gadget? • What effect might this have on the cost of the object? • Could the changed performance of the gadget be done more easily with some other device? • Could we combine some of these gadgets to make new and interesting inventions that serve several functions? • How might the design incorporate green/sustainable engineering principles?	In teams, students describe how they would change the original design.	Vocabulary: *however, but, on the other hand, contrarily*, etc.
3. Ask some students to share their ideas with the whole group.		
4. Explain that the student teams will make a poster to show their ideas for redesigning their gadget.	Student teams create a poster showing how they would adapt their gadget for a new use and why that change might be needed.	
5. Facilitate the teams' presentations.	Teams explain their posters to their peers and the teacher, focusing on how their new design represents an improvement on the original.	The original design _____. [Change preposition] our new design _____ because _____.

Day 4: Evaluate *Mechanisms- Reverse Engineering*

Teacher Says/Does	Student Says/Does	Language requirements
1. Explain that engineers will often complete applications and proposals to receive funding to support their ideas for designing/redesigning gadgets.		
2. Show the following quote from the NSF website and ask students to analyze and explain the main ideas that should be included in the Project Summary [overview, intellectual merit, and broader impacts of project]. "Each proposal must contain a summary of the proposed project not more than one page in length. The Project Summary consists of an overview, a statement on the intellectual merit of the proposed activity, and a statement on the broader impacts of the proposed activity. The **overview** includes a description of the activity that would result if the proposal were funded and a statement of objectives and methods to be employed. The statement on **intellectual merit** should describe the potential of the proposed activity to advance knowledge. The statement on **broader impacts** should describe the potential of the proposed activity to benefit society and contribute to the achievement of specific, desired societal outcomes. The Project Summary should be written in the third person, informative to other persons working in the same or related fields, and, insofar as possible, understandable to a scientifically or technically literate lay reader. It should not be an abstract of the proposal" (National Science Foundation, 2016, p. II-9).	Student pairs explain the main ideas of the Project Summary in their own words.	Third person sentences, technical vocabulary: This project seeks to _____ The objectives include ____
3. Review the writing style guidelines and record student responses for beginning the Project Summary. You can use a student example or refer to the redesigned gadget example from earlier lessons.		
4. Have student teams complete the NSF grant proposal (**5.4.3**) for their own redesigns. While they are working, use the Students will **Collaborative Dialogue Template** (p. 32 Teacher Handbook) to guide conversations and take a running record of students' progress on content and language objectives.	Student teams complete the application for funding their proposal that clearly describes the improvement that their design offers.	See handout for additional sentence stems.

Figure 1

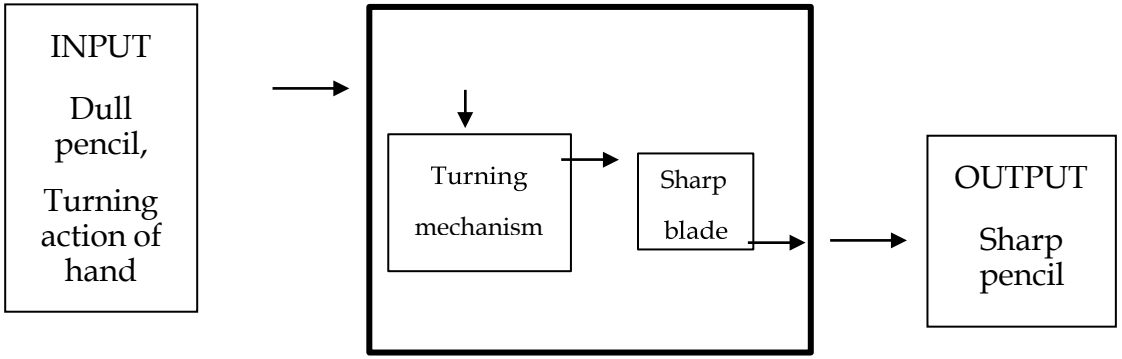
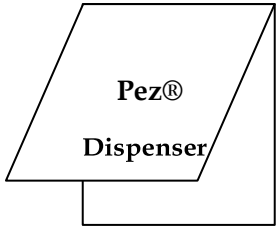


Figure 2



Exit Slip: Reverse Engineering

Name: _____ Date: _____

Look around the room and select two gadgets that move. Identify the kind(s) of motion that the gadget makes and predict how the mechanism inside the object allows it to move.

Gadget	Motion	Prediction
		I predict that there is/are _____ inside this gadget. I predict that the object moves by _____ _____
		I predict that there is/are _____ inside this gadget. I predict that the object moves by _____ _____

Exit Slip: Reverse Engineering

Name: _____ Date: _____

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Gadget	Motion	Prediction
		I predict that there is/are _____ inside this gadget. I predict that the object moves by _____ _____
		I predict that there is/are _____ inside this gadget. I predict that the object moves by _____ _____

Reverse Engineering

Engineers use a problem-solving approach called *reverse engineering* to figure out how a gadget works and could be made to work better.

Carefully study the outside of your gadget and the way it works.

1. How was it designed?

2. How does it work?

3. What did the designers have to consider when they planned it?

Now, *reverse-engineer* your gadget:

4. Draw what you think is inside. Label how you think it works.

5. Take the gadget apart. What are the parts and what do they do?

Part (name or draw)	Size	What does it do?

6. If you could make this gadget better, what would it be able to do?

7. How you would redesign it so it is better?

“National Science Foundation” Grant Proposal

Work with your team to write a grant proposal based on the real application from the National Science Foundation. With the NSF as your audience, your proposal “should be written in the third person, informative to other persons working in the same or related fields.” (National Science Foundation, 2016, p. II-9).

Part I: Overview

This project seeks to _____

_____

_____

The objectives include _____

_____

_____

In order to accomplish these objectives, the engineers would _____

_____

_____

Part II: Intellectual Merit

This project has the potential to advance knowledge by _____

_____

_____

_____

_____

Part III: Broader Impacts

As a benefit to society, the project _____

_____

_____

_____

_____

Information adapted from:
http://www.nsf.gov/pubs/policydocs/pappguide/nsf16001/gpg_print.pdf