Design Technology in Engineering Education for English Learners: Project DTEEL

NSF DRK-12 # 1503428

University of Texas, Austin

Fifth Grade
Lesson Plans
Units 1-8

DTEEL Fifth Grade Lessons

Unit 1 (Materials):
Green Music Makers

Concept

We can manufacture things so that they are easier on the environment by making it easy for people to recycle them. "Green design" takes into account the entire life cycle of the product.

Content Objective

Investigate properties of materials and create a musical instrument that fits specifications, then rate its green design.

Language Objective

Evaluate the sustainability of the project using comparative adjectives: e.g., *better, stronger, friendlier*, and *safer*.
Express and support an opinion about the role of sustainability in future engineering projects in school and beyond using modal verbs: e.g., *should, could, might, will.*
Write an explanation about sustainability in engineering.

Standards

- **NGSS:**
    - **5-ESS3-1:** Obtain and combine information about ways that communities use science ideas to protect the Earth's resources and environment.
    - **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:**
    - **1B** Students will make informed choices in the conservation, disposal, and recycling of materials.
    - **2F** Students will communicate valid conclusions in both written and verbal forms.
    - **3D** Students will connect grade-level appropriate science concepts with the history of science, science careers, and contributions of scientists.

- **ELPS:**
  - **2C** Students will learn new language structures, expressions, and basic and academic vocabulary heard during classroom instruction and interactions.
  - **3G** Students will express opinions, ideas, and feelings ranging from communicating single words and short phrases to participating in extended discussions on a variety of social and grade-appropriate academic topics.
  - **3H** Students will narrate, describe, and explain with increasing specificity and detail.
  - **5G** Students will narrate, describe, and explain with increasing specificity and detail to fulfill content area writing needs.

Materials

Design Materials:

- Chart paper & pens, one per team of two students, handouts 5.1.1-5.1.4.

Construction Materials:

- Cereal boxes, margarine tubs, other containers; connectors (e.g., string, brads, staples, glue) construction materials (e.g. rubber bands, paper plates, straws, cardboard tubes)

Literature Connection:

- Awesome Dawson by Chris Gall

Day 1: Engage/Explore *Materials- Green Music Makers*

Teacher Says/Does	Student Says/Does	Language requirements
1. Preparation: Make an anchor chart of the Materials Cycle (Handout **5.1.1**). 2. Recycling: Pair students up and pose the following questions: What is recycling? How is recycling done? Why do people recycle? 3. Discuss recycling and the Materials Cycle referring to the anchor chart. Review how recycling saves energy. Say one of the most important activities in recycling is sorting into materials types. 4. Materials: Have the children select an object from the classroom and tell what materials they think are combined to make it.. Ask student pairs to consider the questions below about their selected objects: • Would you have to take it apart? • Would it be easy or hard to take apart? How would you do it? • When you take it apart, how many different materials do you have? *5.* Ask one or two of the children to describe or act out how they would recycle the object they are showing. Ask the children to tell why it is easier on the environment to make things that are easy to recycle (refer to the Materials Cycle). *If we use less energy, it is better for the environment.* 6. Green Design: Explain that some engineers specialize in designing for the environment. They use "green design," earth-friendly strategies and materials. 7. Ask students to discuss how engineers might plan a new toy so it would be earth-friendly. Write down some of their ideas. They might include: a. Use recycled/used materials b. Make the designs easy to take apart and sort c. Use natural materials that break down in the earth	After students have time to think, they share their answer with their partner then share out to the class. Children talk about how they might recycle in their home. Students discuss questions in pairs. Students share responses in whole group.	Recycling is ________________. Recycling is done by ___________. It would be (easy/simple/hard/difficult/challenging) to take apart because ______________.

d. Use materials that are easy to re-make into new products, like aluminum 8. Consider showing one example of green design called biomimicry: https://www.youtube.com/watch?v=FBUpnG1G4yQ 9. Give students the exit slip on green design (Handout **5.1.2**).	 Students complete exit slip.	

Day 2: Explore: *Materials- Green Music Makers*

Teacher Says/Does	Student Says/Does	Language requirements
1. Display the Materials Cycle anchor chart. Ask students to describe the cycle to a partner. Remind students that we use recycling and green design to save energy and review the design problem. 2. Tell students that they will be working as engineers *using green design to make a musical instrument.* Explain that they will be working in teams and should use their listening and speaking skills to work together to make their instruments. Show children the Design Brief (handout **5.1.3**) and the rating scale for green design so they know how their project will be judged. 3. Construction: 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.	Students discuss the materials cycle in pairs. The teams work independently to make a Design Brief with several preliminary sketches, select one they like, and add any necessary details.	

Day 3: Explain/Elaborate *Materials- How Green Is Your Musical Instrument?*

Teacher Says/Does	Student Says/Does	Language requirements
1. Tell students that they will share their instruments during a design review. Explain that a "design review" is a discussion in which teams present their plans and models-in-progress for friendly review and collaborative problem solving.	Student teams take turns sharing their progress on the design challenge. Other teams ask questions of the presenters.	
2. As the other teams ask questions of the presenters, think about what they know and are using in their design. Facilitate a conversation among the students and give suggestions.		We were wondering ______________________.
3. Explain that the teams will have the remainder of class to make adjustments to their instruments based on feedback from the design review.	Teams revise and extend their green design instruments. Upon completion, the team should score their product using "How 'green' is your musical instrument" handout. They should prepare to present their instrument explaining how they met the specifications of the design problem.	One thing your team might try is __________________. We thought that your ______ was creative because _________. Comparative adjectives: *better, stronger, friendlier*, and *safer*.

Day 4: Elaborate/Evaluate *Materials- Green Music Makers*

<table>
<tr><th>Teacher Says/Does</th><th>Student Says/Does</th><th>Language requirements</th></tr>
<tr><td>1. Explain that each team will present their completed musical instrument and explain how they met the specifications of the design problem.

2. Ask the students to organize themselves into one or more bands and play a simple tune using their instruments. After you enjoy the music, use handout 5.1.4 to discuss and score their instruments:
a. Would it be hard to make a real musical instrument using the Green Design rules?
b. Would it be hard to make a car using the Green Design rules? How might it be done?
c. How might you have changed your musical instrument to get a higher score?
d. Did you have to “de-bug” or “trouble-shoot” in your design (find and correct problems).

3. Write the following quote on the board: “The world sends us garbage…we send back music.” Favio Chávez, Orchestra Director Explain that they will watch a short video of a group of students from Paraguay who are using green design in very creative ways. Landfill Harmonic video:
https://www.youtube.com/watch?v=wCjbd21fYV8
Lead a discussion on the director’s quote and how it relates to social and environmental justice. Possible questions include:
• What do you think the director meant?
• Why do you think he said that the world sent them trash?
• Is it fair that some countries produce much more trash and pay other countries to store it in landfills?
• What do you think the video didn’t show?

4. Consider reading the book, Funny Bones by Duncan Tonatiuh, to emphasize how the artist José Guadalupe Posada always included messages in his artwork. Ask the students how they think this could relate to their drawing and designing in their engineering work.</td><td>Students should play an active role in rating each instrument, holding up number cards for each category. Everyone should understand the reasons underlying the ratings, and the team can share their self-rating.

Students practice playing their instruments and create a simple tune. They share their responses to the whole group discussion questions.

Students discuss the questions in pairs and then whole group.</td><td>Comparative adjectives: better, stronger, friendlier, and safer.</td></tr>
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5. Tell students that they will write a “Makers’ Philosophy” describing their vision for engineering that they would like to follow throughout the school year. 6. Analyze the structure and language of the school mission statement or district philosophy. Model the process of drafting a philosophy statement, highlighting specific features of the language and structure of the example text. 7. Answer individual student questions as they write their “Makers Philosophy.”	Students write their “Makers Philosophy” about principles of engineering that they feel are important in their future classes.	In our future engineering projects, sustainability ______________________. Prepositions: because, since, as a result, moreover, furthermore, in addition, etc.

Unit 2 (Structures):
Bridges on a Budget

Concept

When we use what we know, we can build strong structures. The budget for a design project influences the design we choose.

Content Objective

Students work in "construction company" teams to make a bridge that meets a cost constraint; they use equivalent scales to determine both the value of different bridge characteristics and to score their bridges' performance.

Language Objective

Use visual and linguistic support to understand different bridge characteristics.
Express and support **opinions** using first person present tense verbs and prepositional phrases: e.g., *therefore, as a result, thus, and so*.

Write a **persuasive** letter using newly acquired prepositional phrases.

Standards

- **NGSS:**
    - **5-PS1-3:** Observe and measure to identify materials based on their properties. 5-PS1-4. Investigate whether mixing two or more substances results in new substances.
    - **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.
    - **3-5-ETS1-3:** Plan and carry out fair tests that control for variables and identify failure points to improve a model or prototype.
- **TEKS:**
    - **2A** Students will describe, plan, and implement simple experimental investigations testing one variable.
    - **2E** Students will demonstrate that repeated investigations may increase the reliability of results.
    - **3A** Students will analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing**.**
    - **3D** Students will connect grade-level appropriate science concepts with the history of science, science careers, and contributions of scientists.

- **4A** Students will collect, record, and analyze information using tools**.**
- **4B** Students will use safety equipment, including safety goggles and gloves.
- **6D** Students will design an experiment that tests the effect of force on an object.

- **ELPS:**
  - **2E** Students will use visual, contextual, and linguistic support to enhance and confirm understanding of increasingly complex and elaborated spoken language.
  - **3E** Students will share information in cooperative learning interactions.
  - **5F** Students will write using a variety of grade-appropriate sentence lengths, patterns, and connecting words to combine phrases, clauses, and sentences in increasingly accurate ways.

Materials

<u>Design Materials:</u>

- A copy of Bridge Design Brief (**5.2.2**) on a chart or overhead transparency
- Copies of handouts **5.2.3-5.2.5** one for each team of 4, crayons or markers, three colors per team
- Blank overhead transparencies and wipe-off pens (one each per team)

<u>Construction Materials:</u>

- One "kit" for each team with the following associated costs: **plastic straws** (50, 3 cost units each); **craft sticks** (10, 7 cost units each); **poster board** (1 sheet, 9 cost units per half sheet) **paper** (10 sheets, 1 cost unit each); **string** (4 one meter lengths, 1/2 cost unit per length) **tape, glue** (all you want, no cost assessment)

<u>Investigation Materials:</u>

- the bridge "canyon" and "island" set up on a table: 26 inches (65 cm) wide canyon made between two stacks of books 8 inches (20 cm) off the table, with a 4 x 6 inch index card as an island
- Metric rulers or meter sticks
- Calculators
- Weights [at least 5 pounds (about 2.3 kg)]

<u>Literature Connection:</u>

- <u>Twenty-One Elephants</u> by Phil Bildner

BACKGROUND INFORMATION

An important advancement in bridge engineering was the pre-Columbian Inca technique for creating suspension bridges. These bridges were essential to connecting the vast network of roads throughout the Inca Empire. Some of the bridges spanned canyons over 150 feet, making them longer than any bridges in Europe at the time. When the Spanish conquistadors arrived to South America, they were unfamiliar with suspension bridge technology and they marveled at the Incas' engineering. Without these bridges, the Spanish would never have been able to traverse the numerous canyons with their horses and cannons. Ochsendorf estimates that just *one* of the cables from the larger bridges could support 50,000 pounds. As a testament to their craftsmanship, many of the Inca bridges survived through the 19th century. One bridge near Huinchiri, Peru is still in use today. As part of an annual ceremony, the local people cut down the bridge and rebuild it using grass and plant fibers from their surroundings. Contemporary stress ribbon bridges in Europe, and now in the United States (the first of which was built in Fort Worth, TX in 2012), emulate the technology of Inca suspension bridges. However, the Inca bridge-building process uses local materials and more sustainable techniques since the bridges are completely biodegradable and do not contribute to climate change.

Sources: Ochsendorf, J. (2005, Dec 8). Engineering in the Andes Mountains: History and design of Inca suspension bridges [Video file]. Retrieved from: http://www.loc.gov/today/cyberlc/feature_wdesc.php?rec=3839

Texas Department of Transportation. (2012, Sep 17).*The TXDot update: News and information from the Texas Department of Transportation.* Retrieved from: http://www.txdot.gov/txdot_library/newsletters/txdot_update/2012/091712.html

Day 1: Engage *Structures-Bridges on a Budget*

Teacher Says/Does	Student Says/Does	Language requirements
1. **Preparation:** Collect, measure, and set out the materials kits, and build the bridge “canyon’ with a stack of books. Tape a 4 x 6 inch index card to the table between the stacks of books. This makes an “island.” If you do not have sets of masses available, prepare some with zip bags of sand or rock, using a bathroom scale. The bags should fit onto the 6 inch (15 cm) wide bridge roadbeds. If possible, borrow weights from a high school science teacher or from a gym. 2. Begin by showing images of famous or unique bridges from around the world (Inca bridge, Golden Gate Bridge, Brooklyn Bridge, a local bridge, etc.). Consult “Remarkable Bridges” (handout **5.2.1**) 3. Guide students to the conclusion that **appearance, cost**, and **strength** are important factors in building a bridge. On an anchor chart, sketch a bridge and add the words **Appearance, Cost**, and **Strength** each with a small picture clue. Refer to this chart throughout the process. 4. Show students ***Design Brief (5.2.2)***. Tell them that they will be working as engineers to design a bridge that has quality **appearance, cost, and strength.** The bridges will be scored on: a. **Appearance.** Each team will rate other teams’ bridges on a scale of 1 to 10. Calculate the average of these scores. Criteria for determining aesthetic quality include creativity/novelty, texture, form (symmetry, “lines”, etc.), pattern, and color. b. **Cost.** Each materials kit represents 250 cost units. Teams may return materials from their original kit if all in one piece and may return 1/2 sheets of posterboard. Teams may “purchase” additional materials, which will be charged at the rates given above. These additional materials may NOT be returned for credit, whether used	Students make observations with a partner on the different bridge designs and discuss what was involved in the building process. They share out to the class, highlighting appearance, cost, and strength as important factors in bridge building.	Vocabulary: appearance, cost, strength

or not, and they will be added to the total cost. The cost of the bridge will be figured using the equivalent scale on handout **5.2.3** "*Finding Your Bridge's Cost and Strength Scores*." Help students practice with these scales. c. **Strength** (Load capacity). Bridges will be loaded along their lengths until failure, or until they have used up all available weights. The bridge must support the load for 5 seconds. The strength score of the bridge will be figured using the equivalent scale. 5. A simple formula gives the bridge score, but in order to have students participate in and understand the weighted nature of the scoring, try this activity: "What's it Worth?" Circulate among the students to guide their discussions using handout **5.2.4.** 6. Help the whole group come to consensus after teams have made their decisions, then use these IMPORTANCE values in all bridge scoring calculations.	Students discuss and decide the "IMPORTANCE" (relative mathematical weight) of the bridges' cost, strength, and appearance. Using a scale of 100, (which results in a percentage-of-total value), students engage in dialogue.	

Day 2: Explore *Structures-Bridges on a Budget*

Teacher Says/Does	Student Says/Does	Language requirements
1. Remind students that they will be working in teams and should the evaluation criteria from the previous lesson. Show students Design Brief. 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. Approve bridge designs as the teams finish their plans. Keep account of costs of additional materials that the teams request and credits for any they return.	Student teams should create a design plan for their bridges using a blank transparency or a piece of paper to be shown on the document camera. Their plans should include top, side, and end view drawings of the proposed bridge (to scale, if appropriate), and should be labeled to indicate materials to be used. Teams obtain materials kits and construct their bridges. As teams are making bridges, they should also keep an account of the material costs.	Vocabulary: appearance, cost, strength Express and support opinions using first person present tense verbs: I think ___________________ I observe _________________ It is my opinion that ________

Day 3: Explain *Structures-Bridges on a Budget*

Teacher Says/Does	Student Says/Does	Language requirements
1. After the first versions of the bridges are completed, hold a "design review." You should ask questions such as: • Show the path the compression load force will follow when we put a lot of weight on your bridge. • Have you put the strongest members under the compression load? 2. As the other teams ask questions of the presenters, think about what they know and are using in their design. Facilitate a conversation among the students and give suggestions. 3. Explain that the teams will have the remainder of class to make adjustments to their bridges based on feedback from the design review.	Each team presents and explains its design to the class. Other teams should ask questions as well. Teams revise their bridges as necessary after the design review.	I think that ______________. I appreciate how/that/your ______________________. I am surprised that ______________________. *therefore, as a result, thus, and so*, etc.

Day 4: Elaborate/Evaluate *Structures-Bridges on a Budget*

Teacher Says/Does	Student Says/Does	Language requirements
1. Explain that each team will present their bridge for judging. The scores for the bridges will be determined by adding up the weighted data. Review "Scoring Your Bridge" handout **5.2.5**.	Students vote on appearance and strength is tested.	
2. When the judging is completed, discuss with students the following questions: • Were you surprised at your final bridge score? • What effects did the IMPORTANCE scores have on your final score? (Sentence stem: The IMPORTANCE values made our score…) • Tell about how you use trouble-shooting skills in your construction. • Did you stay with your plan? If not, why not?	Student teams engage in discussion of the questions.	First person verbs to persuade: I feel that ___________________. I strongly believe that _________. We conclude that _____________. We argue that _______________. I propose that _______________.
3. Model the process of writing a persuasive letter. Make a word web with students' ideas about words and phrases used to persuade an audience. Explain that students will write a persuasive letter that argues for certain weights for different categories on the rubric and explains their rationale.	Students write their persuasive letters individually or in pairs.	*therefore, as a result, thus, and so*.

Unit 3 (Mechanisms):
Mechanimals Design Project

Concept

Mechanisms can change direction of motion.

Content Objective

Teams make a toy or device from context that changes linear to rotary motion or vice-versa.

Language Objective

Articulate cause and effect relationship using past tense verbs.
Explain changes in motion using new vocabulary.
Persuade using drawings and increasingly complex written sentences.

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**.**
- **ELPS:**
    - **1E** Students will internalize new basic and academic language by using and reusing it in meaningful ways in speaking and writing activities that build concept and language attainment.
    - **3E** Students will share information in cooperative learning interactions.
    - **5G** Students will narrate, describe, and explain with increasing specificity and detail to fulfill content area writing needs.

Materials

<u>Construction Materials:</u> access to all materials from Units 1 & 2 including wheels, gears and pulleys
Handouts **5.3.1-5.3.2**
<u>Literature Connection:</u>

- <u>Galimoto</u> by Karen L. Williams

Day 1: Engage *Mechanisms: Mechanimals Design Project*

Teacher Says/Does	Student Says/Does	Language requirements
1. Choose a context for the toy. It could be characters from a book read in class, a zoo animal, or a local mascot, etc.		
2. Write the following words on the board and conduct a game of Charades where one person acts out the word and others have to guess which word it is. **levers, pulleys, changing direction of motion, input motion, output motion, systems of mechanisms, black box models, cams** - wheels with off-center axles or odd shapes and paths (This is introduced in 2nd grade lessons; you may wish to go over some cams and models with your students in order to have options for the design models in this lesson.) As each word is guessed, go into further explanation to make sure students understand the concept. Review all words once more as a class by pointing to the word and then doing the Charades motion while saying the word.	Individual students act out vocabulary words while the others guess.	Vocabulary terms: Brick Words: levers, pulleys, changing direction of motion, input motion, output motion, systems of mechanisms, black box models, cams Mortar Words: cause/effect, articulate, persuade
3. Discuss with students the context of their design either previously chosen by the teacher or selected as a class. It could involve some of their interests from literature, other studies, or current events. Ask if they can think of some working models they could design and make to demonstrate that interest.		
4. Explain the vocabulary exit slip (**5.3.1**)	Students complete the exit slip.	

Day 2: Explore/Explain *Mechanisms: Mechanimals Design Project*

Teacher Says/Does	Student Says/Does	Language requirements
1. Show the teams ***Design Brief (5.3.2)*** Mechanisms-Explore/Explain): Changes linear motion to rotary motion or rotary motion to linear motion. Use Charades motions to accompany words as a review. Remind students of the following features of creating their Design Brief: • Ask questions about what the words mean. • Talk with your partner and plan what you might like to make. • Draw a Design Brief for the work that needs to be done. • Draw a side-view sketch of what you would like to make. 2. Let the teams begin their work on their Design Brief with access to all construction materials. Monitor the classroom asking and answering questions. 3. 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.	Student teams complete their Design Briefs. Once the maps are approved, they begin building the toy with changing motion.	

Day 3: Explain/Elaborate *Mechanisms: Mechanimals Design Project*

Teacher Says/Does	Student Says/Does	Language requirements
1. Hold a design review with the teams and their models in progress. Ask the teams to demonstrate their products as they are (it is perfectly acceptable if the mechanisms are not fully completed). Ask them to explain where and how the direction of motion was changed. Model use of the sentence stem.	Each team presents and explains its design to the class.	The input: ______ motion changed to the output ______ motion because…
2. Encourage the rest of the class to ask the team questions about their products.	Other teams should ask questions as well.	
3. Explain that the teams will have the remainder of class to make adjustments to their mechanisms based on feedback from the design review.	Teams continue working on their mechanisms and incorporate feedback from the design review.	

Day 4: Evaluate *Mechanisms: Mechanimals Design Project*

Teacher Says/Does	Student Says/Does	Language requirements
1. Explain that students will have the opportunity to create advertisements for their mechanisms that explain how the device changes motion. 2. Brainstorm some ideas with the group about how they could persuade their 5th grade peers about the importance of their gadget. 3. Circulate around the room as the student teams create advertisements on chart paper.	Students brainstorm ways to persuade their peers. Student teams work on their poster advertisements.	Vocabulary terms: levers, pulleys, changing direction of motion, input motion, output motion, systems of mechanisms, black box models, cams

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.	
6. Explain the exit slip (**5.4.1**).	Students complete exit slip individually.	I predict that there is/are ______________________ inside this gadget. I predict that the object moves by ______________________

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*

<table>
<tr><th>Teacher Says/Does</th><th>Student Says/Does</th><th>Language requirements</th></tr>
<tr><td>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</td><td></td><td></td></tr>
<tr><td>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?</td><td>In teams, students describe how they would change the original design.</td><td>Vocabulary:
however, but, on the other hand, contrarily, etc.</td></tr>
<tr><td>3. Ask some students to share their ideas with the whole group.</td><td></td><td></td></tr>
<tr><td>4. Explain that the student teams will make a poster to show their ideas for redesigning their gadget.</td><td>Student teams create a poster showing how they would adapt their gadget for a new use and why that change might be needed.</td><td></td></tr>
<tr><td>5. Facilitate the teams' presentations.</td><td>Teams explain their posters to their peers and the teacher, focusing on how their new design represents an improvement on the original.</td><td>The original design ____________. [Change preposition] our new design _______________ because _________________________.</td></tr>
</table>

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].	Student pairs explain the main ideas of the Project Summary in their own words.	
"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).		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

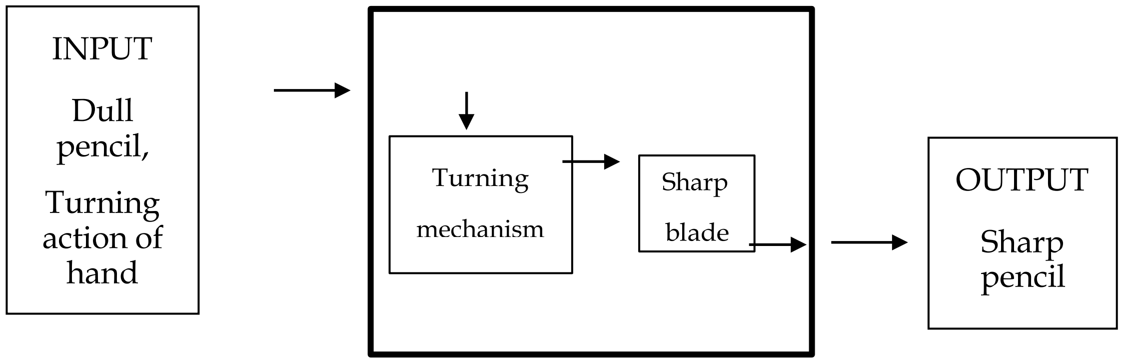
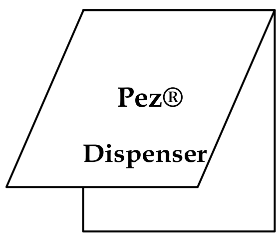


Figure 2



Unit 5 (Work & Energy): Measuring Elasticity

Concept

Forces Cause Change
The distance a rubber band stretched per unit of force is its elasticity.

Content Objective

Student teams determine the elasticity of three different rubber bands and then use one of those rubber bands to find the weight of an object.

Language Objective

Internalize new academic language through meaningful usage.
Explain energy changes using complex sentences and verb phrases based on previous learning.
Discuss projectile motion and energy using different vocabulary and parts of speech: *elastic, elasticity*.

Standards

- **NGSS:**
  - **5-PS1-3:** Observe and measure to identify materials based on their properties.
  - **5-PS1-4:** Investigate whether mixing two or more substances results in new substances.
  - **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.
  - **3D** Students will connect grade-level appropriate science concepts with the history of science, science careers, and contributions of scientists.
  - **5A** Students will classify matter based on physical properties, including mass, magnetism, physical state (solid, liquid, and gas), relative density (sinking and floating), solubility in water, and the ability to conduct or insulate thermal energy or electric energy.
  - **6D** Students will design an experiment that tests the effect of force on an object.

- **ELPS:**
  - **1A** Students will use prior knowledge and experiences to understand meanings in English;
  - **1E** Students will internalize new basic and academic language by using and reusing it in meaningful ways in speaking and writing activities that build concept and language attainment.
  - **2G** Students will understand the general meaning, main points, and important details of spoken language
  - **3B** Students will expand and internalize initial English vocabulary by retelling simple stories and basic information represented or supported by pictures.

Materials

<u>Investigation Materials</u>

- A washed and shrunken stocking, tube top, woolen glove, or other clothing item (optional)
- Packages of rubber bands, three different standard sizes (try to get types that are quite different in thickness and length)
- One paper clip (or "S" hook) per apparatus
- Apparatus with ruler to hang rubber bands and weights (see suggestions below)
- Set of prepared weights from 5 ounces to 5 pounds, or use metric weights in grams or kilograms, converting to Newtons using 0.1 kilogram as an approximate equivalent of one Newton
- 1 wood craft stick
- Mystery weight, something you can hook with a paper clip. For example, fill a baggie with pebbles to make a weight of 2.5 pounds
- Scale to confirm weight of unknown in pounds or ounces Safety goggles for each student
- Calculators to compute averages
- Copies of Handout **5.5.1**

Literature Connections

<u>Plastic Man</u> comic book series by Jack Cole

BACKGROUND INFORMATON

What is Potential Energy?

First, what is energy? Energy is defined as the capacity of matter to perform work as a result of its motion, its position, or its internal state. *Kinetic* energy is energy of motion. *Potential* energy, then, is energy of position or internal state. A bucket of water above a well, with its rope wound around an axle, has potential, or *stored* energy that will be released when the rope unwinds. The chemical energy in fuels and batteries is potential energy also.

Forms of Stored Energy

Elasticity Springs, including rubber bands, return to their original shape and dimensions after experiencing a load that changes their shape. This is elasticity. Within their intended range of performance springs continue to be elastic. If too much of a load is put upon springs, they deform and are no longer elastic.

Gravitation A body on the earth's surface works against the gravitational field to stay upright. Moving the body to a higher height causes an increase in potential energy.

Chemical Energy Fuels and food are forms of chemical energy. Calories, for example, are units of energy, specifically the amount of energy needed to change the temperature of one gram of water by one degree Celsius. The calories in your apple are potential energy that is released when the apple is consumed.

Children's Ideas About Energy

Keep in mind that most students—even through high school—do not understand that energy is conserved. For example, in an electrical circuit, energy is not "lost" as a light bulb burns; the energy simply changes to heat and light and then dissipates. It only is "used up" in the sense that WE can't further use the heat or light, but the energy is not consumed. It is difficult to prove this also when potential energy is changing into kinetic energy, because you cannot see it. The big idea that you CAN help children understand while they are still learning concretely is that potential energy is stored energy, then go on with some interesting ways to study and use it.

More About Springs

The shape, material, and elasticity of a spring depend upon its intended use. Springs to close doors are *extension springs*: they stretch open and their elasticity pulls them closed (and the door with them); springs to push staples along in your stapler are *compression springs*: they are squashed, then they apply a force along the staple row. Springs are made in many other shapes for a variety of uses. When engineers need a machine component that will push or pull and then return to its shape, they get the precise measurements of the distance to be covered and the force to be applied, then they use a standardized table to find the spring they need.

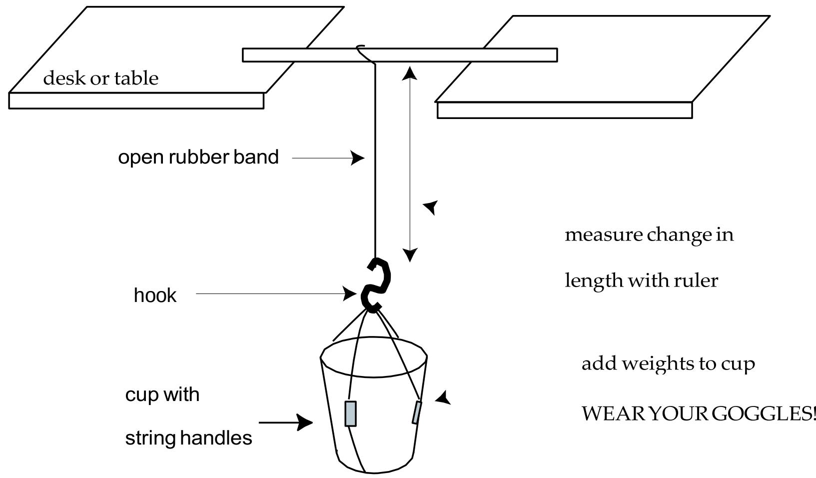
Measuring Elasticity

We determine elasticity or *stiffness* by measuring the change in length of a spring or rubber band as force is applied. The elasticity is expressed as force divided by masses in Newtons (metric force units) you express the elasticity in Newton-meters. The stiffness in the spring, then, is tied to the potential energy in the spring. If you utilize that stiffness to launch a projectile, the distance traveled depends on the stiffness and, therefore, potential energy of the spring.

Children can carry out an investigation with rubber bands to determine elasticity. Since rubber bands are not designed to stretch with precision, and they can lose elasticity, you will need to find packages of rubber bands that are fairly uniform and then, if you are

a stickler for accuracy, change out the rubber band every time a new weight is applied.
Ideally, children will see a proportional relationship between force and distance. In other words, if a one-pound weight stretches the rubber band one inch, then a 2-pound weight will stretch the rubber band two inches distance. For example, if a spring stretches from 9 to 9.5 inches when a force of 10 pounds is applied, we say the elasticity is 20 pound-inches (10 pounds force divided by the 0.5 inch stretch). If you are using

Preparation If necessary, prepare a set of weights to use in the investigation; also, set up one or more sets of elasticity measuring equipment. Here is an example:

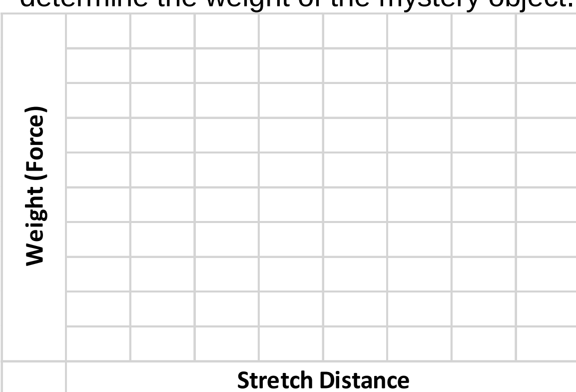


Day 1: Engage *Work & Energy- Measuring Elasticity*

Teacher Says/Does	Student Says/Does	Language requirements
1. Hold up the shrunken article of clothing (see materials list). Ask the students if they think you can use the article again. If they have had some experience with elasticity, they may know you can stretch the clothing back out to its proper shape. Use the word *elastic* to talk about things that stretch or shrink but then return to shape. Write the words *elastic, elasticity* and *stored energy* on the board.	Students share their ideas with the whole group.	Vocabulary terms ***Brick words:*** *elastic, elasticity, stored energy, bungee cord, spring scale* ***Mortar words:*** *apparatus, graph, plot*
2. Ask the children if they think the sweater (or other) has energy stored in it. Can they think of other stretchy things that store energy till it's needed? Think about cars or propellers driven by rubber bands. Demonstrate the following:	Students discuss their ideas.	
Have a child hold up two fingers, one from each hand. Stretch a rubber band between the fingers. Weave a wood craft stick in the center of the rubber band and wind it up. Let it go and the stick will spin. The rubber band stored energy until you released it.	One student helps with the teacher demonstration.	
3. Look around the room for other types of stored energy, such as things that stretch, objects in raised positions (coat on a coat hook) or objects with chemical energy such as batteries.		
4. Ask students if they think it is important for engineers and other designers to know exactly how much something stretches? Tell students to listen as you read them a story and that their job is to help you finish the story. Say "**For her birthday, *Jessica* wanted to do something crazy. She had been learning about elasticity in class and she wanted to go bungee jumping! (Project an image of a person preparing to bungee jump.) She was worried though. If the designer was wrong about the length of the stretched cord, what might happen?"** Have students share possible outcomes if the cord stretched longer or shorter than	Students share their ideas with a partner.	

predicted. Ask if there is a way to measure the amount of elasticity in the rubber bands and have students share ideas with a partner		

Day 2: Explore/Explain *Work & Energy- Measuring Elasticity*

Teacher Says/Does	Student Says/Does	Language requirements
1. Explain that students will be testing elasticity of three different rubber bands, much like the designer of the bungee cord. Have the students help set up the apparatus they will use to measure the elasticity of the three rubber band types. 2. Give each team of students a copy of "*Rating Rubber Bands"* (**5.5.1**) handout so they can begin their investigation. Please be sure students wear safety goggles to protect their eyes from flying hooks or weights if rubber bands snap! 3. While the students are working, use the **Collaborative Dialogue Template** (p. 32 Teacher Handbook) to guide conversations and take a running record of students' progress on content and language objectives. 4. If your class has experience with line graphs, help them set up graphs such as this and plot the points. When teams have completed their measurements, they are to use a rubber band to determine the weight of the mystery object. 	Student teams test the elasticity of the three rubber bands. While they conduct the tests, they plot the elasticity measures on a line graph.	

Day 3: Elaborate/Evaluate *Work & Energy- Measuring Elasticity*

Teacher Says/Does	Student Says/Does	Language requirements
1. After the students have plotted the results of the three rubber bands, ask the following questions: • How were the results from the three trials different? • Would they say their rubber bands make dependable weighing devices? Why or why not?	Students discuss their ideas in small groups and then share with the whole group.	
2. Show students a spring scale. Ask: How does it work? After giving students think time, have them sketch their understanding of how the spring scale works.	Students draw their ideas of how the spring scale works.	
3. Have students share their ideas in a whole group discussion until arriving at the following conclusion: The spring in the spring scale has a known elasticity, or *spring value* that can reliably determine weight.	Students discuss their ideas in the whole group.	
4. Students write questions and answers for a test. The questions should reflect an in-depth understanding of the vocabulary for the unit.	Student pairs write questions and answers for a test of the information from the unit.	Complex sentences: Based on your different trials, The line graph demonstrated ______, which helped illustrate ________________.

Unit 6 (Work & Energy):
Elastic Launcher

Concept

We can use our information about elasticity to select a rubber band that will launch a load a predictable distance.

Content Objective

Students will design and make elastic systems that will launch a wet cotton ball or a ping pong ball to a target. They will select rubber bands and predict the distances based on their data about elasticity.

Language Objective

Cooperate with peers on collaborative building and writing activities.
Predict results of different launches using specific vocabulary: *stored energy, elasticity*, etc.
Explain how device works in cohesive written paragraph.

Standards

- **NGSS:**
  - **5-PS1-3:** Observe and measure to identify materials based on their properties. 5-PS1-4. Investigate whether mixing two or more substances results in new substances.
  - **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.
  - **3-5-ETS1-3:** Plan and carry out fair tests that control for variables and identify failure points to improve a model or prototype.

- **TEKS:**
  - **2A** Students will describe, plan, and implement simple experimental investigations testing one variable.
  - **2C** Students will collect information with detailed observations and accurate measuring.
  - **2E** Students will demonstrate that repeated investigations may increase the reliability of results.
  - **5A** Students will classify matter based on physical properties, including mass, magnetism, physical state (solid, liquid, and gas), relative density (sinking and floating), solubility in water, and the ability to conduct or insulate thermal energy or electric energy.

- **6A** Students will explore the uses of energy, including mechanical, light, thermal, electrical, and sound energy.
- **6D** Students will design an experiment that tests the effect of force on an object.

- **ELPS:**
  - **1E** Students will internalize new basic and academic language by using and reusing it in meaningful ways in speaking and writing activities that build concept and language attainment.
  - **3E** Students will share information in cooperative learning interactions.
  - **5B** Students will write using newly acquired basic vocabulary and content-based grade-level vocabulary.
  - **5G** Students will narrate, describe, and explain with increasing specificity and detail to fulfill content area writing needs.

Materials

Design Materials

i. Overhead transparencies/chart paper and pens (1 per team of two); Handouts **5.6.1-5.6.3**

Construction Materials

ii. Cotton balls, ping pong balls, or other safe projectiles; notched wood craft sticks, wood strips, blocks of wood, NEX, LEGOs, or other construction set components; Plastic spoons, cloth, or other material for holding projectiles before launch; Rubber bands of the 3 types used previously; Wood glue or glue gun; Calculators; Safety goggles

Literature Connection

The Three Little Pigs Build a Catapult by Janesa Hendriks and Olivia Petersen

Preparation

Decide on the target (if any) or whether the launching event will be for distance only. You might have students launch wet cotton balls at a bulls-eye marked with points, or; toward lines on the floor that show distance, or into buckets. If you are launching wet cotton balls they will mark butcher paper where they land. Determine what projectile you will use. Plan to monitor construction areas for safety and set safety standards for team practice-launches.

Day 1: Engage *Work & Energy- Elastic Launcher*

Teacher Says/Does	Student Says/Does	Language requirements
1. Write the words *stored energy* and *elasticity* on the board and ask for their definitions. Allow students think time, have them share their definitions with a partner, and then share out to the class. In similar Think, Pair, Share fashion have students think of examples of stored energy around the classroom and then how the energy is then used. Some examples are wind-up toys, or putting loads on springs.	Students think about their responses, discuss with a partner nearby, and then share with the whole group.	Predictions: I predict that ______ will _____________________. Vocabulary terms:
2. Ask students to review what they found out about elasticity in the last activity. They should have some data on the elasticity of the 3 types of rubber bands. Ask them to label the rubber band supply boxes, if not done so already, with the approximate force per inch the rubber band provides.	Students discuss and label the rubber band boxes.	***Brick words:*** *stored energy, elasticity*, ***Mortar words:*** collaborate, cooperate, predict, device
3. Ask these questions and have students discuss with their teams: • Which rubber band is most stiff? Would it hold the most energy? • Could you use what you learned to make a rubber band-operated toy that launches a ball to a target? (or whatever projectile and goal you will use.)	In teams, students discuss the questions and share their ideas in the whole group.	
4. Have students individually complete the 'What I Know' and 'What I Want to Learn' sections of a KWL chart (**5.3.1**) as their exit slip.	Students complete the KWL chart individually.	

Day 2: Explore/Explain *Work & Energy- Elastic Launcher*

Teacher Says/Does	Student Says/Does	Language requirements
1. **Preparation:** Make a KWL anchor chart by synthesizing the students' responses from the previous lesson's exit slips.		
2. Review the KWL chart with the students and add any new information or questions that they have.	Students share additional thoughts and questions for the KWL chart.	
3. Show students the target or goal of the launcher activity and present the Design Brief (**5.6.2**). Let the teams investigate some of the variables in using the rubber bands to launch. For example, the distance the rubber band is stretched makes a big difference in available elasticity. Handout **5.6.3** may be used to guide the discussion.	Students work in teams to experiment with the rubber bands' elasticity.	
4. Have the teams make drawings on the overhead transparencies or paper to be shown on the document camera. Then hold a design review to go over the plans. Other teams should ask questions. **The students will be held to their choice of rubber band, so this review provides their chance to alter their decision. During the design review they should explain why they are using the rubber band selected.**	Teams draw the plans for their rubber band launchers.	
5. Let the teams begin construction. 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.	Student teams begin building their launchers.	

Day 3: Elaborate/Evaluate *Work & Energy- Elastic Launcher*

Teacher Says/Does	Student Says/Does	Language requirements
1. After the student teams have finished building their launchers, ask how they might be used in real life. 2. Show examples in sports (for projectile motion), rocketry, aerospace engineering, historical research, and civil engineering. Consider showing the video below: "Projectile Motion" by the Children's Museum of Houston https://www.youtube.com/watch?v=R4LPxQ90ju8 3. Describe how student teams will write and illustrate a creative story that explains the mechanisms, work, energy, and purpose of their launcher.	Students share their ideas.	
4. Model how you would identify characters, setting, problem, and solution for the example of putting away laundry from the video above. "Think aloud" so as to make the process more transparent for students. Consider modeling the idea generation process using the graphic organizer below. Also demonstrate how to write the first part of a narrative story.* http://thisreadingmama.com/wp-content/uploads/2012/11/Fiction-Text-Structure-Retelling-Organizer.pdf	Students ask questions and contribute suggestions for the graphic organizer and story writing process.	***Mortar words:*** characters, setting, problem, solution
5. Circulate around the room as the student teams complete the graphic organizers and write their own stories. *You may want to dedicate an additional class period to having the students rewrite their initial thoughts from the graphic organizer to narrative form as a creative story.	Student teams complete the graphic organizer and use it to write a creative story about their launcher.	

Day 4: Evaluate *Work & Energy- Elastic Launcher*

Teacher Says/Does	Student Says/Does	Language requirements
1. After the student teams have built their devices and written the stories, hold the launching event.	Student teams take turns reading their stories. After all teams have presented, then each team launches and records their scores.	
2. Have students share observations of what helped certain devices be more or less successful.	Students share their observations of the stories and launchers.	

Unit 7 (Systems):
Inventing with Control Logic

Concept

We can invent new toys and devices after defining what chain of events needs to occur in the device.

Content Objective

Teams design new gadgets with two or more moving parts.

Language Objective

Infer potential solutions to a design problem by making connections with prior knowledge of engineering.
Provide constructive feedback to peers in oral speech and writing.
Summarize chain of events using a *topic sentence* and *conclusion*.
Describe solution using *complex sentences*.

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:**
  - **2A** Students will describe, plan, and implement simple experimental investigations testing one variable.
  - **2C** Students will collect information with detailed observations and accurate measuring.
  - **2E** Students will demonstrate that repeated investigations may increase the reliability of results.
  - **2F** Students will communicate valid conclusions in both written and verbal forms.
  - **6A** Students will explore the uses of energy, including mechanical, light, thermal, electrical, and sound energy.
  - **6D** Students will design an experiment that tests the effect of force on an object.

- **ELPS:**
  - **3E** Students will share information in cooperative learning interactions.
  - **4J** Students will demonstrate English comprehension and expand reading skills by employing inferential skills such as predicting, making connections between ideas, drawing inferences and conclusions from text and graphic sources.

- **5B** Students will write using newly acquired basic vocabulary and content-based grade-level vocabulary.
- **5E** Students will employ increasingly complex grammatical structures in content area writing commensurate with grade-level expectations.
- **5G** Students will narrate, describe, and explain with increasing specificity and detail to fulfill content area writing needs.

Materials

Design Materials: Paper, Stickies, Blank transparencies/Chart paper and pens, one per team of two

Construction Materials: posterboard, tagboard, glue guns, string, straws, and craft sticks; Electric circuit supplies, including wire, batteries, lights, resistors, relays, and switches, syringes and plastic tubing, clamps, screws and wood strips for making a structure; Tools including screwdrivers, pliers, and drills

Literature Connections

Save My Rainforest by Monica Zak (Spanish/English), and *Baby Coyote and the Old Woman* by Carmen Tafolla (Spanish/English)

Day 1: Engage *Systems: Inventing with Control Logic*

Teacher Says/Does	Student Says/Does	Language requirements
1. Conduct a *Think, Pair, Share* activity discussing the practical importance of engineering by posing the question: If you asked an engineer why his/her work is important, what do you think s/he would say? Allow students time to think, then to share their ideas with a partner, then call on students to share with the class. 2. Focus students in on the importance of engineering in designing solutions to problems. Prepare three different problem scenarios from fiction, history, or community service. Here are some examples of design problems you (or the students) might choose from or you may design your own: a. From Tafolla's *Baby Coyote and the Old Woman*: The Old Woman's human neighbors ask for her help because so much trash has accumulated around their town that they cannot pick all of it up to recycle. Design and make a mobile device that can pick up objects and sort them according to material. b. People who lived in castles a long time ago had no way to tell if visitors approaching were friendly or not. Design and make a model of a gadget that would let you know someone had arrived at your gate and whether or not you should let them in. c. The nursing home down the street is looking to hire people, but, in the meantime, their staff is having trouble keeping up with all the folks who need medications on time. Design and make a device that dispenses pills on schedule and reminds or notifies an elderly person when it's time to take the dose. They will predict problems with the device and write how to trouble-shoot in those instances in a chart. 3. List each scenario on an anchor chart with accompanying pictures. 4. Have students brainstorm needed characteristics of the gadget for each problem scenario: (ie. small, energy-efficient, quiet, etc.)	Students think, discuss with a partner, and then share their responses in the whole group. Students work in pairs to record the characteristics for a gadget for each scenario.	***Brick words:*** ***Mortar words:*** *infer, solutions, making connections, feedback, summarize, chain of events*

5. (OPTIONAL) As the exit slip, have each student rank the scenarios in terms of interest.	Students rank the scenarios.	Complex sentences, topic sentence, and conclusion. *First of all,* *Initially,* *The main problem was* *In conclusion,* *Finally,* *Lastly,*

Day 2: Explore/Explain ***Systems: Inventing with Control Logic***

Teacher Says/Does	Student Says/Does	Language requirements
1. **Preparation:** You may consider grouping students according to their interests in the scenarios.		
2. Each team will choose one scenario and begin their detailed design plan on chart paper. Show the children the following constraints: a. Their gadget must have at least two moving parts. b. They must be able to explain their gadget and the chain of events that make it work. c. They will make a diagram after they are done.	Students create a detailed plan for building a gadget that meets the design criteria.	
3. Meet with each team as they create their plans and begin to construct their gadgets.	Once they have teacher approval for the initial design, students begin to build their gadgets.	

Day 3: Explain/Elaborate *Systems: Inventing with Control Logic*

Teacher Says/Does	Student Says/Does	Language requirements
1. Once the teams have completed their plans, hold a "silent gallery" design review to involve the entire class in analyzing the planned gadget and asking questions of the design team. Review respectful sentence stems that the students can use to help structure their feedback.	Students walk around the classroom with writing utensils and/or sticky notes and add questions, comments, suggestions to each design plan.	
2. Explain that the teams will now have the chance to modify their gadgets based on their peers' feedback.	Student teams finish building/adjusting their gadgets.	I like how your team __________. I wonder why ________________. I would suggest that __________. I had not thought about _______.

Day 4: Evaluate *Systems: Inventing with Control Logic*

Teacher Says/Does	Student Says/Does	Language requirements
1. After the gadgets are finished, have teams present by scenario. For each scenario, invite students to compare the advantages and challenges of each gadget using a T-chart. While the teams present, consider asking the following questions. You may want to provide them to the groups before having them present in front of their classmates. • What are the advantages and disadvantages of your gadget? • When did you use trouble-shooting, or when did you have to "de-bug" your invention? • If you made lots of these gadgets, what steps would you probably need in manufacturing?	Student teams present their gadgets and suggest advantages/disadvantages for each gadget.	Complex sentences, topic sentence, and conclusion.
2. After the finished gadgets are presented, have the teams trade gadgets to see if another team can operate it.	Student teams try to operate the different gadgets from each scenario.	
3. Have students create a small poster as an ad for their invention which accompanies it on display. Brainstorm criteria for quality; some criteria could include: • Attractiveness of lay-out • Effectiveness of message for target audience • Legibility • Incorporation of complex sentences	Students help determine the criteria for quality work and they work in teams to create ads for their inventions.	

Unit 8 (Systems):
Rube Goldberg Greetings

Concept

We can apply what we learned in some inventive fun.

Content Objective

Student teams design and make a device that meets specifications.

Language Objective

Demonstrate understanding of causation using drawing and increasingly specific academic vocabulary.
Summarize reflections on learning in DTEEL using specific vocabulary.
Report a group consensus in writing using past tense verbs: *determined, concluded*, etc.

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:**
  - **1A** Students will demonstrate safe practices and the use of safety equipment**.**
  - **1B** Students will make informed choices in the conservation, disposal, and recycling of materials.
  - **3A** Students will analyze, evaluate, and critique scientific explanations by using empirical evidence, logical reasoning, and experimental and observational testing**.**
  - **3D** Students will connect grade-level appropriate science concepts with the history of science, science careers, and contributions of scientists.
  - **4A** Students will collect, record, and analyze information using tools**.**
  - **4B** Students will use safety equipment, including safety goggles and gloves.
  - **6A** Students will explore the uses of energy, including mechanical, light, thermal, electrical, and sound energy.
  - **6D** Students will design an experiment that tests the effect of force on an object.

- **ELPS:**
  - **1C** Students will use strategic learning techniques such as concept mapping, drawing, memorizing, comparing, contrasting, and reviewing to acquire basic and grade-level vocabulary
  - **3D** Students will connect grade-level appropriate science concepts with the history of science, science careers, and contributions of scientists.
  - **3E** Students will share information in cooperative learning interactions.
  - **3H** Students will narrate, describe, and explain with increasing specificity and detail.

Materials

Design Materials:

Copy of the design problem; Blank overhead transparencies and pens, 1 set per team of 4; Handouts **5.8.1-5.8.2**, Copies of Rube Goldberg cartoons

Construction Materials:

All construction materials previously used; Tools; Circuits and components, OR hydraulic systems, OR stiff paper

Literature Connection
Rugy Goldberg's Bright Idea by Anna Humphrey

BACKGROUND

<u>Who was Rube Goldberg?</u>

A cartoonist known for his comical drawings of elaborate machines, Rube Goldberg cleverly found and drew the *most complicated* method of getting a simple job done. Making toast, for example, might require seventeen machine steps, starting with flossing of false teeth!

Today's Rube Goldberg competitions are quite different from invention fairs, for true inventions are prized if they make work easier, not more complex. A Rube Goldberg competition prizes overdone effort and is a good test of ingenuity.

See an old magazine article at this blog, http://blog.modernmechanix.com/meet-rube-goldberg/#more

Mr. Goldberg offers this description of an invention anyone is free to mass-produce, should they care to. It's a method for getting a dull comedian offstage. Here's how it works:

1. A barber shop quartet sings a sad song.
2. It's so sad a little man standing nearby cries big tears into a flower pot.
3. The plant in the pot grows until it tickles the bare feet of a boy sitting atop a slide.
4. The kid slides down, bumps a Civil War bugler at the bottom.
5. Bugler wakes up, leaps to his feet and begins blowing reveille in another Civil War vet's face.
6. Second vet catches cold from the breeze and sneezes into a propeller.
7. Propeller revolves, operating two hands holding broom.
8. Broom sweeps comedian off stage or platform.

Other resources are online for contests to design the most complicated series of steps to accomplish a function:
http://www.purdue.edu/newsroom/rubegoldberg/ http://contest.rubegoldberg.com/?page=team&id=IS289

<u>The Potential for a Schoolwide Engineering Fair</u>

If other teachers are using these lessons, plan to hold an Engineering Fair together! It could be held in conjunction with a science fair, invention, technology, or even a cultural fair.

Preparation

Secure a space for the devices to be assembled and displayed. Also, set a budget for the materials to be used. Consider the materials' actual costs for this task, then write the costs on labels. Budget is not a judging factor in this design, so students should not feel they are forced to avoid electric circuitry as a means to solve the problem. Students may work in teams of up to four. Make invitations to administrators, parents, partners, and the media once you know when the devices will be completed.

Day 1: Engage *Systems: Rube Goldberg Greetings*

Teacher Says/Does	Student Says/Does	Language requirements
1. Begin whole group by telling students about Rube Goldberg's biography and fame as a cartoonist. Information about his life, along with videos and cartoons can be found at: https://www.rubegoldberg.com/about/ 2. Split students into teams and give each team a different copy of one of his cartoons. Give the teams time to look at their cartoon to determine the sequenced steps. They may write them down if needed. Model the use of past tense verbs to express consensus. 3. Have students share their cartoon with the class on the document camera by describing in complete sentences the list of events in their cartoon and the end product.	Students analyze the cartoon contraptions and articulate the sequence of steps. Students share their cartoons and analysis with the rest of the class.	***Brick words:*** ***Mortar words:*** *specifications, causation, summarize, reflections* past tense verbs: *determined, concluded*

Day 2-3: Explore/Explain *Systems: Rube Goldberg Greetings*

Teacher Says/Does	Student Says/Does	Language requirements
1. Read to the teams the Design Brief (**5.8.1**). Discuss with the students what most people would think of a simple welcome mat or a sign on the door. Ask: But how would *Rube Goldberg* treat this challenge?	Students share their ideas about welcoming guests to the school based on their knowledge from the previous lesson.	
2. Have students begin working on their design plan, which they draw and label on chart paper.	Student teams create a design plan on chart paper.	
3. Conduct a design review asking students to show and explain their plans before they begin. Students may give suggestions or ask questions about other teams' designs.	Students present their initial plans and other teams ask questions and give suggestions and feedback.	past tense verbs: *determined, concluded*,
4. Direct the student teams to begin construction. Circulate around the classroom encouraging discussion and collaboration. 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.	Student teams adapt their plans and begin construction.	

Day 4: Elaborate *Systems: Rube Goldberg Greetings*

Teacher Says/Does	Student Says/Does	Language requirements
1. Once the teams have completed their contraptions, discuss the creation of engineering portfolios, and how these will help them present their learning to an audience (**5.8.2**). 2. Model selecting a piece of quality work that represents one of the four major areas of the DTEEL curriculum: 1) Materials, 2) Structures, 3) Mechanisms, and 4) Work & Energy/Systems		past tense verbs: *determined, concluded*,
3. Conduct a "think aloud" to model the 3R reflection process (Retell, Relate, Reflect) using sample stems from the portfolio Design Brief. Write simple sentences at first. **Retelling** involves summarizing the purpose of the work, **relating** involves connecting it to other projects and ideas in the curriculum, and **reflecting** involves synthesizing the learning that resulted and the continuing questions that emerged from the work. 4. Invite students to expand upon your simple sentence reflections, thereby creating complex sentences.	Students think about expanding the sentences, discuss in pairs, and then share in the whole group (think-pair-share).	**Retell** This was about _________. I noticed that __________. **Relate** This reminds me of _____. What I found especially meaningful was ________. **Reflect** Now I understand that __. I learned that _________. A question that I have is ____________________.
5. Direct student teams to select quality work and complete their written reflections on the individual pieces. Each member of the group should select at least one piece to present, and each group should have at least one piece for each of the four DTEEL categories (materials, structures, mechanisms, work & energy). 6. As the teams work on their portfolios, circulate around the room and provide assistance as needed. Help students connect their previous work to their Rube Goldberg contraptions.	Student teams work together to compile their portfolios and write reflections on the individual pieces.	(Adapted from Rolheiser, Bower, & Stevahn, 2000).

Day 5: Evaluate *Systems: Rube Goldberg Greetings*

Teacher Says/Does	Student Says/Does	Language requirements
When the teams are ready to demonstrate their devices, plan to bring in parents and other classes. Use the non-competitive awards in the back of this book, or have judges honor the projects that meet the specifications.	Student teams present their portfolios to the audience, and explain their Rube Goldberg designs.	past tense verbs: *determined, concluded*, **Retell** This was about _________. I noticed that __________. **Relate** This reminds me of _____. What I found especially meaningful was ________. **Reflect** Now I understand that __. I learned that _________. A question that I have is _____________________. (Adapted from Rolheiser, Bower, & Stevahn, 2000).