Iterating Rube Goldberg Machines

Companion Lesson to X-STEM All Access Episode "Combining STEM Superpowers"

Grade/ Grade Band: High School	**Topic:** Physical Science and Engineering

Brief Lesson Description:
Design, build and refine Rube Goldberg Machines to convert mechanical energy into sound energy and practice the skill set of iteration. Students will use a computer simulation to explore the idea, learn associated vocabulary and then construct a device using common materials. They will finally explain how energy is converted in their device.

Performance Expectation(s):
HS-PS3-3: Design, build, and refine a device that works within constraints to convert from one form of energy into another form of energy.

Specific Learning Outcomes:
-Students will create an operational definition for the term "iteration".
-Students will identify helpful strategies to use when iterating a device to optimize performance.
-Students will differentiate between energy transfers and transformations and then analyze these ideas in a Rube Goldberg Device.
-Students will design and optimize a Rube Goldberg Device to show both energy transfers and transformations.
Students will write a scientific explanation of how a Rube Goldberg Device demonstrates the Law of Conservation of Energy.

Narrative / Background Information

Prior Student Knowledge:
Students should know that:
-There are many forms of energy including mechanical, thermal, radiant, nuclear, chemical, electromagnetic (light), sonic (sound), gravitational, magnetic, elastic, etc. Each of these forms can be classified as kinetic or potential.
-Energy in a system cannot be created or destroyed – instead it is transferred between objects or converted into new forms.
-Criteria are requirements that must be met by a design
-Constraints are limitations that must be worked within to create a design

Science & Engineering Practices:

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 9–12 builds on K–8 experiences and progresses to explanations and designs that are supported by multiple and independent student-generated sources of evidence consistent with scientific ideas, principles, and theories.

- Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and trade off considerations.

Disciplinary Core Ideas:

PS3.A: Definitions of Energy

- At the macroscopic scale, energy manifests itself in multiple ways, such as in motion, sound, light, and thermal energy.

PS3.D: Energy in Chemical Processes

- Although energy cannot be destroyed, it can be converted to less useful forms—for example, to thermal energy in the surrounding environment.

ETS1.A: Defining and Delimiting an Engineering Problem

- Criteria and constraints also include satisfying any requirements set by society, such as taking issues of risk mitigation into account, and they should be quantified to the extent possible and stated in such a way that one can tell if a given design meets them. *(secondary)*

Crosscutting Concepts:

Energy and Matter

- Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system.

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering and Technology on Society and the Natural World

- Modern civilization depends on major technological systems. Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks.

Possible Preconceptions/Misconceptions:
-Energy is only found in "living" organisms.
-Energy is only associated with movement (kinetic energy).
-Energy is a fuel, rather than a fuel storing energy.
-All energy forms are equally as useful.

LESSON PLAN – 5-E Model

ENGAGE: Opening Activity – Access Prior Learning / Stimulate Interest / Generate Questions:

This lesson will start with students watching part of the X-STEM Episode "Combining STEM Superpowers" featuring Tamara Robertson. After watching the X-STEM video, discuss the following prompts as a class:
-What does the term "iteration" mean?
-Tamara Robertson talked about how her plans kept changing/iterating. What is a situation from your own life when your plans had to be iterated?
-The term iteration is often used in the engineering design process. What experience do you have with modifying or improving something that you design or construct?

Explain to students that the rest of this lesson is going to provide us with an opportunity to practice the skill set of iteration while investigating how energy is transferred and transformed within a system.

In this lesson, the device we are going to be investigating is called a Rube Goldberg Machine. Sometimes designing a silly, round-about way to do something can enable one to better understand the inner details of the more practical, direct solution. Whenever a machine is made too complicated to do a simple job, it is called a "Rube Goldberg".

Rube Goldberg's award-winning cartoons satirized machines and gadgets. These cartoons combined simple machines and common household items to create complex and wacky contraptions that accomplished mundane and trivial tasks. His inventions became so widely known that Webster's Dictionary added "Rube Goldberg" to its listing, defining it as "accomplishing by complex, roundabout means what seemingly could be done simply."

Show "The Cog" Video. After the video discuss the following prompt as a class:
-Why do you think it took more than 600 takes to make this video? How does that show the idea of iteration?

EXPLORE: Lesson Description – Materials Needed / Probing or Clarifying Questions:

Hand out the STUDENT ANSWER SHEET for this lesson. (You may use physical copies or provide the digital version in Google Docs.) Each student will need a device with internet access to complete this portion of the activity.

Students will start to explore the idea of iterating devices by playing the game "Dynamic Systems" from engineering.com. As students complete the game, they should consider the following prompts:

- ***What strategies did you use to figure out the solution to each level?***
- ***Were there levels that were particularly challenging? For those levels, what strategies did you use to iterate your design?***
- ***As you progressed to higher levels, how did you approach beating them?***

Discuss these prompts as a class after the activity. Help students to make the connection that as systems/devices become more complex, they will need more iteration.

EXPLAIN: Concepts Explained and Vocabulary Defined:
Energy Transfer: process by which energy is relocated from one system to another, for example, through the transfer of heat, work or mass transfer.

Energy Transformation: processes that convert energy from one type (e.g., kinetic, gravitational potential, chemical energy) into another. Any type of energy use must involve some sort of energy transformation.

Law of Conservation of Energy: The law of conservation of energy states that energy can neither be created nor destroyed - only converted from one form of energy to another. This means that a system always has the same amount of energy, unless it's added from the outside.

Students will now review the energy forms and how energy is transferred and transformed in a system. Show the video "Energy Transfers and Transformations" from Dupree Science. As students watch the video, they should take notes about the energy forms and examples of energy transfers and transformations.

After the video, explain to students that in order to consider this information, they will be analyzing the energy transfers and transformations in a Rube Goldberg Device. Have students look at STUDENT ANSWER SHEET and complete section 2. Students will analyze one of the most famous Rube Goldberg devices for energy transfers and transformations. This section can be completed in groups of four and divide the work into the following: Student 1 Steps A-C, D-F, G-I, J-M. They can then share their findings from the whole group to check their thinking together.

After groups complete the section, discuss the three questions as a whole group:
1. What is the difference between an energy transfer and an energy transformation?
2. Are there any energy transfers and/or transformations that are not labeled explicitly in the cartoon? If so, describe below. If not, explain how you came to this conclusion.
3. How does this cartoon illustrate the law of conservation of energy? Use specific evidence from the cartoon to prove that energy is not created or destroyed but instead is transferred or transformed.

ELABORATE: Applications and Extensions:
Students will apply their knowledge of energy transfers and transformations to design a Rube Goldberg device. Specific criteria and constraints for their device are as follows:

Criteria:
-Your machine should include more than four distinct steps.
-Your machine should include at least two energy transfers and two energy transformations.
-Your machine should accomplish at least one of the following tasks:
- -Ring a bell
- -Pop a balloon
- -Fill a cup of water

Constraints:
-1 class period to plan and build
-Use provided materials
-Safely constructable

Review these specifications on Part 3 of the STUDENT ANSWER SHEET.

You will want to provide locally available materials to help students with this task. Suggested materials include:
-Dominos
-Balls of various sizes or marbles
-Cardboard
-String
-Scissors
-Masking Tape
-Desk Bells
-Legos
-Blocks
-Straws
-Cups
-Water
-Balloons
-Cardboard Tubes (Paper towel or toilet paper)
-Paper Clips or binder clips
-Hot Wheels or hot wheels track (available at most dollar stores)
-Popsicle Sticks
-Wax Paper
-Aluminum Foil
-Tinker Toys
-Pull back toys
-ANY OTHER IDEAS YOUR HAVE!

Set a specific time constraint for your building time. (Suggest amount is one class period of 45-55 minutes)

If students appear to be struggling, it is helpful to remind students that it is better to get a few simple steps to work than to have many complex steps that do not work.

EVALUATE:
Formative Assessment:
Formative Question Prompts throughout the lesson are found in ***bold italics*** and student answer sheets.

Summative Assessment:
Students can complete Part 4 of the STUDENT ANSWER SHEET to demonstrate their understanding of this lesson. This Rubric can be used to score responses.

Elaborate Further / Reflect: Enrichment:
Students can extend their knowledge and iteration skills by competing in the Rube Goldberg Institute for Innovation and Creativity competitions found here. There are multiple formats including building physical devices, drawing cartoons, and using minecraft.

SOCIAL EMOTIONAL LEARNING ACTIVITY

CASEL Competency: Relationship Skills
In the X-STEM video, Tamara Robinson talked about the importance of building each other up rather than tearing each other down. Today we will focus on ideas of how to do this in our daily lives.

Start by showing the TEDx Talk "The Power of a Compliment". After the video, pair students up and have them discuss the three following questions:

1. ***What stood out to you from this video?***
2. ***How could you give more compliments to those in your life?***

After providing students time to discuss with their partner, ask for volunteers to share with the whole group.

Tell students that they will now practice giving compliments to one another. Use the Inside Outside Circle Protocol to line students up. Have students give a compliment to the person across from them. Have one circle rotate and repeat the process. After 3-4 rotations, have students discuss the following questions with their partner.

1. ***How did you feel giving compliments? Receiving compliments?***
2. ***How could adding more compliments to your day change your life? Those around you?***

INTERDISCIPLINARY CONNECTIONS/IDEAS

English Language Arts or Foreign Language: Show students the video "4 Revision Principles to Make Your Writing Better." After the video, have students compare and contrast the process of iteration in engineering with the process of revising writing. How are they similar? different?

Computer Science: Have students learn about iteration using loops using this **Lesson from Cambridge.** After the lesson, have students compare and contrast the process of iteration in engineering with the process of iteration in this lesson. How are they similar? different?

Materials Required for This Lesson/Activity	
Quantity	**Description**
Enough for each class	For Rube Goldberg Devices, you will need a variety of the following materials for students to build with: -Dominos -Balls of various sizes or marbles -Cardboard -String -Scissors -Masking Tape -Desk Bells -Legos -Blocks -Straws -Cups -Water -Balloons -Cardboard Tubes (Paper towel or toilet paper) -Paper Clips or binder clips -Hot Wheels or hot wheels track (available at most dollar stores) -Popsicle Sticks -Wax Paper -Aluminum Foil -Tinker Toys

	-Pull back toys

Lesson Created by Jess Noffsinger
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