Engineering Design Process Experience
Adapted for Students with Visual Impairment

I. Effectively Engaging Students with Visual Impairment

Our Guests

- There will be 6 students in grades 7-9 from the VA School for the Deaf and the Blind in Staunton, VA.
- They will be joined by their teacher, Mr. Dylan Boeckmann (JMU Chemistry/Educ. alum), and two orientation and mobility (O&M) specialists- Lisa and Sallie.
- Four students have low-vision and two are blind, they will be in mixed groups with respect to visual impairment (see page 3).
- Dr. Cunningham (Engineering) designed the lesson and will oversee the operation.
- Facilitators: 3 Engineering majors and 5-6 non-engineering students/faculty/staff.

Suggestions for facilitating independence while promoting success

- It's perfectly OK to ask them to describe their vision, "how much vision do you have?", "how do you use your vision?" They are accustomed to and comfortable answering these questions and this information will help you as their facilitator.
- It's OK to use "look" (e.g., "let's look at this one"). They are accustomed to that.
- There may be students who are very capable but will shy away from the activity. If you are unsure how to best facilitate, don't hesitate to ask Dylan or one of the O&M specialists (Lisa and Sallie).
- When you aren't sure if students can do a task (hands-on, problem-solving, etc.) give them an opportunity to do it first and allow enough wait time. If they appear to be struggling to the point of frustration, try talking them through it in more detail or assisting with one piece. If you find yourself doing this a lot, ask Dylan, Lisa, or Sallie to come over to your group.
    - For example, if two of the dominoes in their domino chain are too far apart, you can direct them to feel where the other dominoes are (relative to one another) and then feel the next one and have them think through what the problem is and how to solve it. Instead of just fixing the arrangement for them.
- It may take them a little while to process what they are being asked to do and how to find a particular item so give them time to get the items themselves first. As they are reaching for items, it's OK to say "it's to your left, a little more to your left", "would you like me to get it for you?", "do you need help finding it?"

II. Learning Goals

1. Students will be exposed to and practice the engineering design process.
2. Students will gain an appreciation for how science and mathematics are used in engineering design.

III. Background for Facilitators

What is a Rube Goldberg Machine?

- Rube Goldberg was a cartoonist, inventor, and engineer who is famous for drawing cartoons that depict overly complicated machines that perform very simple tasks, such as a “self-operating napkin.” His ideas were later adapted in movies and in television for comedic effect.
- Rube Goldberg designs are meant to combine the effect of simple machines in a series of events that perform a simple task.
- An illustration of an overly dramatic one is shown in Fig 1. Watch the video on this page for the types of designs we typically see when using this challenge in K-12 education.
- In addition to providing an opportunity for hands-on learning about key principles of physical science and mathematics, this open-ended and collaborative nature of this challenge allows for creativity and humor.

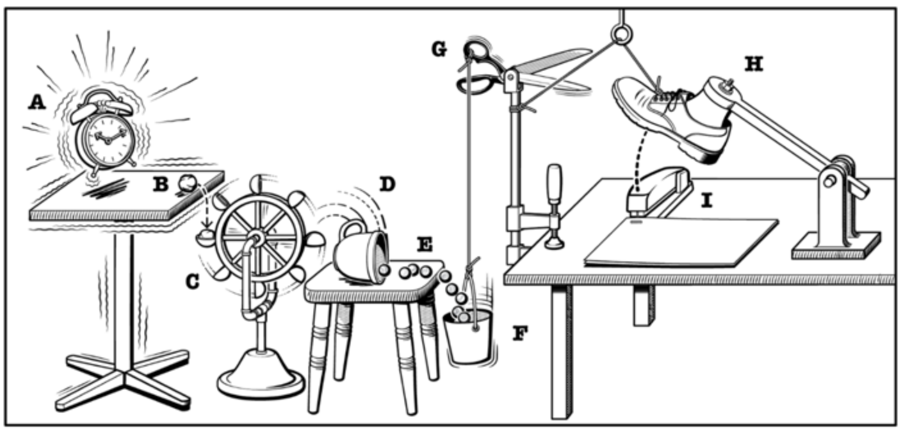


Fig. 1 – Illustration of a Rube Goldberg design

The Engineering Design Process

- The **engineering design process** is a series of steps that guides engineering teams as we solve problems.
- The design process is **iterative**, meaning that we repeat the steps as many times as needed, making improvements along the way as we **learn from failure** and uncover new design possibilities to arrive at great solutions.
- Overarching themes of the engineering design process are **teamwork** and **design.**
- In this lesson, our students will be practicing the engineering design cycle steps: **imagine, plan, create, test, and improve** steps to different degrees depending on their level of independence. These steps are identified throughout the lesson plan. Facilitators are encouraged to use these terms where appropriate in your conversations with the students.

IV. Lesson Introduction (as a whole group)

- Engineering Ambassadors will present on fundamental engineering design. The presentation will define Rube Goldberg mechanisms, discuss the different forms of energy, and the theory behind conservation of energy. This will serve as the "research" part of the design cycle. This presentation is estimated to last for 10 minutes.

V. Set-Up

- The students will be broken up into 3 pairs ("teams"). **Two of these teams will be more comfortable with the creative choice aspect of the activity, referred to here as the "independent teams".** The other team will benefit from more directed guidance with a more structured design process, referred to as the guided team.
- Each team will be seated together at a different table with at least one engineering majors and 1-2 other facilitators. The guided team will have materials at their table. The independent teams will use materials on a common table at the front of the room.

Guided Team

VI. DESIGN PROCESS STEPS

Facilitators: Use this as a guide and adapt as needed for the skills, personalities, and other dynamics of your team.

Design Challenge and Constraints: Using the provided materials and blueprint (next page), design and build a Rube Goldberg-inspired chain reaction that connects physical interaction pairs in which the last pair causes a ping-pong ball to hit a wooden percussion block (providing auditory feedback), with only 1 touch to initiate the series. **Steps 1-4 (green) represent steps in the engineering design cycle described on page 2.**

1. IMAGINE AND PLAN

Overview: The design and materials have already been chosen. While this provides less opportunity for open-ended creativity, it will allow them to focus their attention on other important skills and ways of thinking in engineering design: 1. assembling or building based on description; 2. tactilely exploring the structure of an object to make predictions about how that object could be used; and 3. problem solving**.**

- Facilitators will introduce each item in a reaction pair starting with the final pair (ball and wooden percussion block). To do this, introduce one pair of items at a time and give the students time to tactilely explore the items and listen to the sound the reaction makes (if applicable).
- Next, introduce the ball and the launcher. Allow them to explore, ask how they think it works, and facilitate their understanding as needed.
    - Encourage students to think about how an object might interact with another object based on its shape, size, structure, etc.
- Repeat this with the dominoes, Newton’s cradle, and inclined plane.

2-3. CREATE and TEST:

- Focus their attention back on the final reaction (setting the other materials aside) and describe how the final reaction pair should be arranged to match the blueprint. Give them time to set this up and test it.
- The guests will need to perform two measurements regarding the final launching of the ball.
    - Guests should measure the height of the launcher (where the ball exits) from the ground. The launcher is already set up on a metal stand at a set angle pointing upwards 20^o from the horizon. The height measurement should come out to be around 86 cm, or 0.86 m, or 34 in.
    - The calculations for the range, or flight distance away from the launcher has already been performed and the guests will not repeat these calculations. But the helpers need to inform them that the appropriate range needed based on their height measurement is around 161 cm, or 1.61 m, or 63 in. A plumb line (I will

demonstrate) can be used to generate a point on the ground to start their range measurement from. Have them measure the range on the ground and place a marker such as tape at that location. Please note: we may need to assist the guests in the alignment of the block once they have the measurement marked on the ground as it will be very difficult to perfectly align the block in the path of the ball before launching it the first time. During a trial launch, if the ball does not contact the block, estimate the amount and direction of movement that the block requires for adjustment. Then have the guests make that adjustment based on our description.

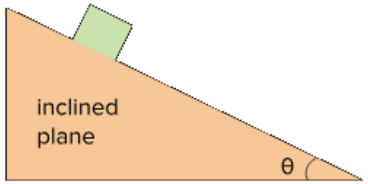
- Repeat working backwards. Ideally, you want them to test each individual reaction while assembling the machine, however:
  - **Tip for facilitating independence:** Allow them to guide the process. For example, if they want to build the entire chain and then test it and then have to rebuild it all again every time they make a modification, let them do that once or twice. You can then point out "this is taking a long time to set up 15 dominoes each time, how could we do this differently?"

4. IMPROVE

Adjustments can be made throughout the process as they test one or more interaction pairs. These adjustments can be re-positioning an item, replacing an item, adding or removing an item, etc.

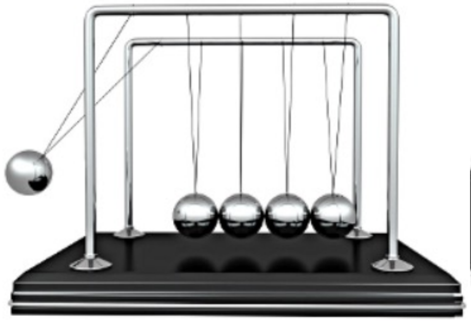
5. DEMONSTRATE/COMMUNICATE: After they finish and successfully test their design, have them practice what they will tell the rest of the class about it.

- For example, start with what the function of their machine is and then what items did they chose to accomplish this and why, where did they struggle, what other combinations did they try that didn't work, etc.

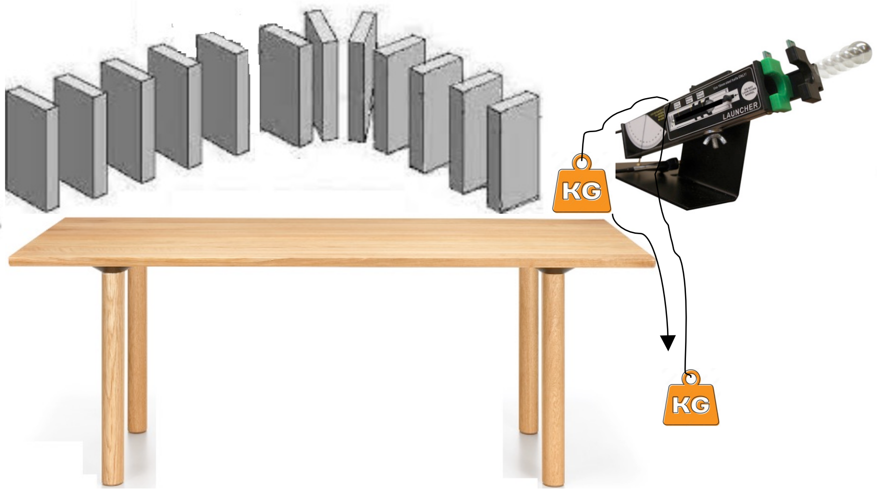


Guests measure θ. This is designed to be the minimum angle necessary to allow the block to slide down the inclined plane. Note: the inclined plane may need to be elevated depending on the next phase.

Creation: Think about how you can use the energy of the sliding block to perform an interaction that will then allow the first ball from Newton's Cradle to fall.



The ball on the left will already somehow be suspended providing it with potential energy. It can rest on a block or similar item that can be knocked over to allow the ball to fall and swing into the others.



The last ball from Newton's Cradle will contact the first domino. Dominos should be placed in an S-shape, at least 15 dominos used. The last domino will knock an item off the table. The falling item will have a string attached to it. The other end of the string will be tied to the firing mechanism of the launcher. The item that falls off the table must have sufficient weight to trigger the firing mechanism.

The launcher is already fixed to a support pole set on the ground with a set launching angle of 20^o. The height of the launcher needs to be measured by the guests. Using this value and the known y-direction velocity of the ball, engineers will calculate (or provide) the flight time of the ball. Using this flight time and the x-direction velocity, the horizontal distance the ball travels will be calculated. The guests will measure this distance along the floor and place a wooden percussion block at the measured point of contact.

Materials

Curved channel slides
Fidget spinners
Pack of balloons
Pack of popsicle sticks
Toy windup cars
Dominoes
Scissors
Red solo cups
Pack of paper clips
Twine/yarn
Pack of push pins
Cup of marbles
Magnetic Buttons
Tennis balls
Pack of command strips
Ping pong balls
Clear solo cups
Plastic straws
Insulated coffee cups
Pack of rubber bands
Pipe cleaners
Blue tape
2 boxes of building blocks~200 pieces
Wooden building blocks~100
Jenga set
Projectile Launcher
Newton's cradle