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.
- 4 students have low-vision and 2 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 your group, don't hesitate to ask Dylan or one of the O&M specialists.
- When you aren't sure if our 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 2 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.

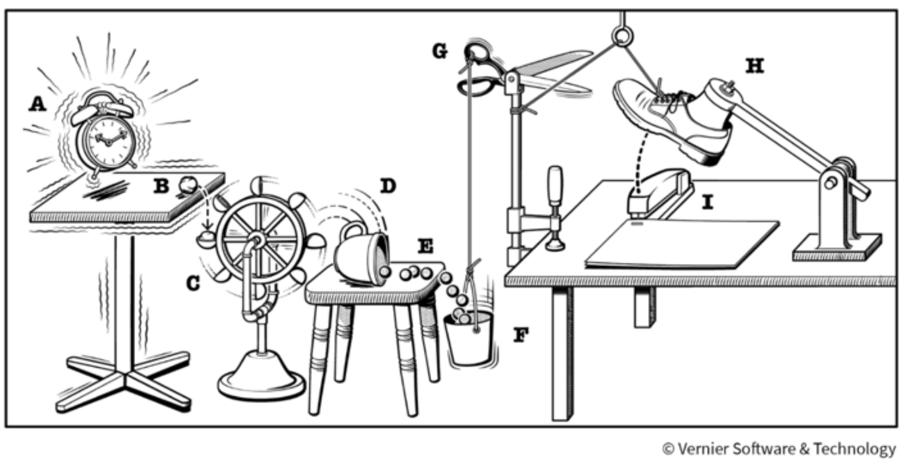

Fig. 1 – Illustration of a Rube Goldberg design

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.

Independent Teams

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: Use the provided materials (see p. 6) to design and build a Rube Goldberg-inspired chain reaction (page 2) that connects physical interaction pairs in which the last pair causes a ping-pong ball to roll off a table into a cup or be launched into a cup, 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: Students will decide what they want their machine to do (e.g., what the function of the machine will be) and then work backwards from there.

A. Make decision about your machine's function:

- Remind your team of the overall challenge and ask them what they would like their machine to do reminding them of the options presented in the introduction:
    - launch a ball into a cup or have a launched ball strike an item like a wooden musical block or a cymbal that would produce a sound to indicate the machine's success.

B. Identify and explore items for final reaction:

- After deciding on the final step in the chain, have them explore the operation of the projectile launcher. They will need to:
    - understand that the launcher needs to be clamped to the table for stability.
    - understand how the trigger mechanism works.
    - understand what can be used to cause the trigger mechanism to be initiated.
    - Review the menu of materials to decide on an item that can initiate the launcher trigger mechanism.
- Help them collect those items from the materials table and give them time to tactilely explore them so they have an idea of relative sizes and structure before deciding how they are going to make that interaction happen. If the final reaction is expected to make a sound they can hear, have them test that as well and think about, "will it be loud enough, what needs to happen to make it loud enough?"

C. Identify and explore items for other reactions:

- Referring to the menu again, have them think about what they can use to cause that final reaction to happen. Collect the materials they decide on. Again, give them time to explore them with their hands before repeating this process again until they have enough materials for at least 4 physical interactions (no limit).

D. Design Sketching

- The team will work together to draw a series of events that rely on force and energy interactions to complete a task.
    - One independent team is low-vision and will be able to draw without assistance. The other is a combination of low-vision and fully blind. The fully blind students will do their drawing using a tactile diagram.
- Once a drawing is complete, facilitators will inspect the drawings and ask questions to provide an opportunity for them to practice communication their ideas, such as
    - "Can you tell me why you picked this material for this part or why these two materials are in this sequence?"
    - "What might we do if that idea doesn't work?"

2-3. CREATE and TEST

Once materials have been collected and drawing discussed, guide them to start with their final reaction and work 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, 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?"

- **Constraints:** To initiate the series of energy interactions, the students may physically touch a part of the design to give an object motion or energy. Once the initial event is started by the students there should be no other external help for subsequent interactions to proceed beyond the energy interactions of the materials themselves.
    - For example, in Fig. 1, the students may touch the initial object at stage A that would set off the alarm clock; however, they may not provide assistance at stage G by touching the scissors in a way that helps it cut the string.

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.

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