Rube Goldberg Machines

A FIVE-SESSION CURRICULUM FOR AFTER-SCHOOL, SUMMER OR DAY-OFF SCHOOL CAMPS

Approximately 10-20 hours of content / discussion / activities

Appropriate for Elementary- and Middle School-aged children with adaptations for more and less advanced students. Could easily be adapted for High-school students.

• Explore six simple machines, find them in your environment and build a simple machine

• Further explore six simple machines and construct a compound machine

• Intro to Design Thinking

• Rube Goldberg Machine Design and Build

• Rube Goldberg Machine Test and Iterate
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Letter from MakerBolder

MakerBolder was created by parents and educators that believe that we all learn more completely (and have more fun while we’re learning), when we are experiencing concepts within the context of the real world, and ideally also in a way that feels relevant to ME!

This unit is created in that vein. We start by introducing students to the simple machines in their own lives — many of which they take for granted — and then give them license to create a wild and wacky machine to do a simple task.

We are grateful to you — the parent, teacher, camp creator (or ??) — for the time you are taking to prepare materials and your own knowledge and skills to teach this class. Have fun!

Sincerely,
The MakerBolder Curriculum Team

Info@MakerBolder.com
Rube Goldberg Camp Overview

Guiding Questions

• What is a machine?
• How do simple machines make our lives easier?
• Can simple machines be combined to perform more complex tasks?
• How can I use my knowledge of simple and compound machines to create my own Rube Goldberg Machine?

GENERAL CONCEPTS

• Machines need energy to work
• Force and Load impact a machine’s function
• Where in our world do we see these machines?
• Simple vs compound machines
• Rube Goldberg - over engineering for a simple task
• Basic design thinking process - design, create, test, iterate, retest
• Teamwork/collaboration - how to be a team player, how to work out differences
• Persistence
• The value of failure
• How to observe a machine and evaluate what’s working and what’s not
• Converting evaluation/observation into a plan for improvement(s)
• Joy of creating/building/inventing

Organization of this Camp

The Camp includes five “Sessions” each of which contains “Lessons” and “Activities” (Lessons are the instructional time, and Activities are hands-on learning time). For each Session, you can expect:

• Welcome – overview of the session
• Lesson – brief intro to topic to activate prior knowledge and generate excitement
• Exploration Activity – hands on learning
• Snack/Recess/Break
• Building/Making Activity
• Consolidation/Conclusion/Clean-up

EACH LESSON IS BUILT WITH THREE SECTIONS:

• Discuss – typically this includes some time for the instructor to ask questions and present materials, followed by prompted discussions
• Explore – simple interactive activities to reinforce the discussion
• Reflect – a brief period of time for students to reflect on their learning, make new observations and/or ask questions

THERE ARE FIVE SESSIONS IN THE RUBE GOLDBERG CAMP:

• Session One: Find and Make Simple Machines
• Session Two: Design Thinking - Planning Compound Machines
• Session Three: Planning our Rube Goldberg Machine
• Session Four: Make Machine Draft One - Build and Test
• Session Five: Make Machine Draft Two - Test and Iterate
### Overview of Sessions

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<tr>
<td><strong>Welcome &amp; Introductions</strong></td>
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<td>What are the steps of the Design Process?</td>
<td>Begin with the end in mind.</td>
<td>Create team roles and clarify activities to build</td>
<td>Continue building, testing and iterating the machine</td>
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<tr>
<th>Second Half of Session</th>
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<tr>
<td><strong>What can we do with Machines?</strong></td>
<td>What is a Rube Goldberg Machine?</td>
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<td>Review your machine and plan supplies</td>
<td>Outline a presentation about your machine</td>
<td>Finalize the presentation Presentation</td>
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<tr>
<td><strong>Build a Simple Machine (catapult)</strong></td>
<td>Plan, build and test a small Rube Goldberg Machine</td>
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<td>Prototype one or two sections of your machine, test and iterate</td>
<td>Test and iterate your machine, capture lessons learned in your presentation</td>
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<tr>
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<td><strong>Name tags / Table Tents</strong></td>
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<td><strong>Examples of Simple Machines</strong></td>
<td>Worksheets</td>
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<td><strong>Craft Supplies to Build Catapults</strong></td>
<td>Pencils, extra paper</td>
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<tr>
<td><strong>Place to store products and supplies</strong></td>
<td>If you are competing in the MakerBolder Rube Goldberg Challenge, you’ll want to prepare the guidelines for the final machines ahead of time and make sure you are familiar with the constraints so you can guide team design(s)</td>
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ACTION
CONSISTENCY
CONSTRAINTS
CRITERIA
FORCE is strength or energy which leads to action or movement – typically a push or a pull action.
FULCRUM is the fixed point on which a lever pivots
INCLINED PLANE is a sloping surface with one end higher. Assists in moving an object to a higher or lower point. (Examples: Ramp, roller coaster, ladder, parking ramp).
INPUT
LEVER a rigid bar resting on a pivot (fulcrum, see below), used to help move a heavy or firmly fixed load with one end when pressure is applied to the other (Examples: seesaw, crowbar, pliers, scissors).
LIMITS
MACHINE is a tool that makes work easier
MECHANICAL ADVANTAGE
OUTPUT
PROCESS
PROTOTYPE
PULLEY is a wheel with a grooved rim around through which a cord passes. A pulley acts to change the direction of a force that is applied to the cord and is chiefly used to raise heavy weights. The combination of two or more pulleys working together reduce the force needed to lift a heavy load. (Examples: Raising the sails on a sailboat, raising the flag on a flagpole, raising the window blinds).
RELIABILITY
ROLES AND RESPONSIBILITIES
REQUIREMENT
RESET
RESULT
SCREW is a rod with grooved threads - great for holding items together or making holes (Examples: screws, nuts and bolts, corkscrew, drill bits).
SEQUENCE
TRIGGER
WEDGE is a triangular shaped tool and is a portable inclined plane. It can be used to separate tow objects or portions of an object, lift up an object, or hold an object in place. (Push pin, knife, ax, doorstop, nail).
WHEEL AND AXLE two-pieces; the wheel is a round disk and the axle is a rod that is connected to the wheel and on which the wheel turns. (Examples: car wheels, steering wheels, rather wheel, mill, bike wheels, screwdriver, cranks and gears).
WORK is a force that acts to move an object
Who was Rube Goldberg?
Reuben Garrett Lucius “Rube” Goldberg lived from July 4, 1883 – December 7, 1970. He started his career as an engineer for San Francisco Waters and Sewers. He resigned to join the San Francisco Chronicle and went on to be a prolific cartoonist. Goldberg is best known for a series of popular cartoons depicting complicated gadgets that perform simple tasks in indirect, convoluted ways, giving rise to the term Rube Goldberg machines for any similar gadget or process.

What is a Rube Goldberg Machine (RGM)?
A Rube Goldberg Machine is a contraption, invention, device, or apparatus that is deliberately over-engineered to perform a simple task in a complicated fashion, generally including a chain reaction. The expression is named after American cartoonist and inventor Rube Goldberg.

Example of a Rube Goldberg machine – in this instance, a complex machine used to turn the television on and off (a simple task).

Why is this important to us?
Tools and simple machines are collectively the most important inventions in human history – transforming work and human relationships, making it easier to grow and prepare food, and making it possible for us to travel to new lands.

We often overlook these items and their importance in our lives – they are, when you take a moment to look around, everywhere. Chances are, you’ve used half-dozen or more of these machines already today.

By working with children to help them become more aware of simple machines in their lives, and then giving them the tools and opportunity to practice their design, build and testing skills – we help them explore science and engineering in a creative and engaging way. This builds confidence, introduces them to failure in a safe and encouraging environment, and builds their ability to spot challenges and implement improvements to build the best machine they can.
SESSION ONE: Finding and Making Simple Machines

Objectives
Understand and recognize the six kinds of simple machines, how they are used, and how they compare/contrast. “I can understand how machines are used to apply or direct force and that they can be mechanical non-electrical devices. I can compare, contrast and categorize simple machines in my environment and I can build a device using simple machine(s) and explain how it works using simple machine vocabulary.”

Overview of Session One
Students will practice recognizing and classifying simple machines in real life and apply what they’ve learned about motion and force by designing and testing a simple machine.

• Welcome & Introductions
• Lesson 1A: What is a Machine? What are simple Machines?
• Activity 1A: Simple Machines Scavenger Hunt
• Break
• Lesson 1B: What can we do with Machines?
• Activity 1B: Build a Simple Machine (catapult)
• Consolidation / Clean-up
VOCABULARY USED IN THIS ACTIVITY
Lever, inclined plane, wheel, axle, screw, wedge, work, force, mechanical advantage

TIME NEEDED
2 hours (timing included in the lesson plan is based on 2 hours, you could make the lesson longer or shorter to suit your needs)

MATERIALS AND SUPPLIES
Name tags / Table Tents – A way for students to write their name and for it to be visible for the instructor throughout the first lesson
Examples of simple machines including bottle openers, Lego wheels/axles, paper towel rolls, door stops, screws, jars, nails, hammers, pulleys (such as on blinds), zippers, etc. If your group is younger or less advanced, bring in samples that are obvious examples (like a doorstop for a wedge); if your group is older or more advanced, bring in less obvious examples (like a baseball bat as a lever, or a ladder as a ramp).
Craft supplies to build Catapults – cotton balls/puffballs, popsicle sticks, rubber bands, plastic spoons.
Worksheets – one copy for each student printed ahead of time
Pens, extra paper – not required, but it’s usually a good idea to have a few extra pens/pencils and some extra paper in case students need it for note taking
Computer / Screen / Projector – if you intend to show any of the resource videos, ensure that you will have internet access in the classroom area, and secure the required computer/screen or TV/projectors, etc. Also, ensure that you have the proper connection cable and power cords.

RESOURCES
Simple machines Wikipedia
Further understanding simple machines here, and here
What Are Simple Machines Video
Simple machines for young students

SET-UP AND PREPARATION
Read through lesson and adapt stories / materials from your experience
Pre-screen any videos or audio materials you intend to use
Build a sample catapult or several samples (Google: tabletop catapults for several ideas of catapults that can be built with popsicle sticks, rubber bands and a plastic spoon)
Print worksheets

BACKGROUND KNOWLEDGE
Students will need very little background knowledge to be successful. It will be important for students to be able to safely handle basic crafting and building tools

LESSON 1A
Timing: 1 hour (expand or compress as needed for your class schedule)

DISCUSS
Worksheet 1A: Simple Machines
ASK: What is a Machine?
DISCUSSION: Machines are devices that help humans move things or apply force
ASK: Do Machines have to have electricity / electronics?
DISCUSSION: There are 6 simple machines that all machines are based off of, they ...
  • merely require the application of a single force to work
  • make work easier
  • are designed to solve problems
  • are not connected to electricity or electronics

Show: The six simple machines (show illustrations of each and/or draw on a white board or easel pad, show an example of each). Students take notes on the worksheet.
  • wheel and axle
  • inclined plane
  • wedge
  • lever
  • pulley
  • screw

TIP:
Collect examples of what machines ARE, what they DO, and how they complete WORK. Use the examples to point out that present-day machines may involve electronics but they still use the simple machines as their basis. This also illustrates that, at their core, what they do can be simplified to “move things.” How they do it will always draw a direct connection back to the six simple machines.
EXPLORE

Supplies: The examples of simple machines that you brought in to the classroom. Make sure you have at least one of each, there’s room on the sheet for multiple examples if you bring in more than one in a certain category.

Explore: In groups, examine the simple machine samples and classify them on your worksheet. What are they used for? Are there similarities? Differences? How do they apply force or help things move?

Worksheet 1A: Simple Machines Scavenger Hunt

DISCUSS: Simple machines are all around us – from doorknobs to forks and truck wheels/axles to curtain pulleys. Look around this room (include the playground or other rooms if appropriate) and see how many you can find. Try to find at least one from each category.

To help you find as many simple machines as possible, refer to the list of machines included in the free digital version of Science Companion Simple Machines unit, pg 27.

Explore: Hand out the scavenger hunt worksheets and set a timer – send them searching for as many as they can find.

NOTE: If there aren’t very many machines nearby, invite students to add more machines by thinking of things that they use every day that may not be in the room.

REFLECT

Facilitation Question Ideas

- Which machines did you see most often? What does that say about how we interact with our environment?
- Did you notice anything that you were doing while you were hunting, where you could have used a simple machine but you didn’t have one?
- What simple machines do you use at home, that you don’t see here? Vice versa – what machines are here that you don’t have at home?

TRANSITION

Now we’ll break for a few minutes, when we come back, we’re going to talk more about “work” – how do machines move things – what forces are involved.

CHALLENGE

ADVANCED STUDENTS

In the discussion – spend more time comparing and contrasting the machines and discussing the different purposes of each.

- Require that students find only compound machines and identify the machine, and all of its machine components.
- Create a competition where students earn points for all the machines they can identify that no one else finds to encourage them to look for more obscure instances of each of the machines
- Add points to the scavenger hunt – they could increase based on volume of items found (for example, the first lever is worth 1 point, the 2nd is 2 points, third is 3 points, etc.

SIMPLIFY

FOR LESS ADVANCED STUDENTS

In discussion – minimize compare and contrast discussions, include more video examples of simple machines at work

- Label many of the examples in the room with a sticky note or red string so that students can easily spot them
- Put the students in groups of 2 or 3 to work together to find more examples
LESSON 1B

Timing: 45 minutes (expand and contract as needed)

**DISCUSS**

**ASK:** What kinds of things can simple machines do?

**DISCUSS:** They can move things by lifting, pushing, pulling, or, they drive things apart or hold them in place. This movement is called “Work” – the machines do WORK.

**ASK:** Can we measure how much work a machine does? Can we measure how hard a machine works?

**DISCUSS:** Work can be measured through the equation:

\[
\text{Work} = \text{Force} \times \text{Distance an object moves}
\]

That also means that . . .

\[
\text{Force} = \frac{\text{Work}}{\text{Distance}}
\]

**ASK:** If your goal is to get to the top of a hill that is 500 feet high - would you rather ride your bike up a very steep hill for 10 minutes, or a more gradual hill for 20 minutes?

**DISCUSS:** We have found simple machines around the room, and we now understand the WORK that a simple machine does.

Now, we’re going to build our own simple machine.

**YOUR ASSIGNMENT:** to build a simple machine that will launch a puffball. It doesn’t have to be perfect, but you should use at least one simple machine to create it. Here are your supplies:

- Rubber bands
- Popsicle sticks
- A plastic spoon
- Puffballs (or marshmallows)

Find complete instructions for building a puff-ball catapult at makerbolder.com, or visit our Pinterest page with many catapult design ideas.

**CHALLENGE**

**ADVANCED STUDENTS**

Create several scenarios for which students must calculate Force, or Work based on variables that are provided.

**SIMPLIFY**

**FOR LESS ADVANCED STUDENTS**

Share the formulas conceptually rather than as specific equations.

“Work can be measured – to understand how much WORK is done, we can look at how much force we apply, and how far we move something.”

Talk about a common scenario – if you wanted to push a toy car – is it more or less work to push it up a hill, versus on a flat sidewalk?
REFLECT

Facilitation question ideas:
• What type of simple machine did you build?
• What could you do to make it launch the puffball higher/farther?
• How is a rubber band like a simple machine?
• Think about WORK, FORCE and MOVEMENT – how did the catapult achieve these three important parts of a simple machine?

Optional Reflection Activity:
On a blank piece of paper, write a letter to someone that didn’t attend this class. Tell them what you learned about simple machines.

TRANSITION TO CLOSE

We've learned a lot about simple machines today. Now that you have the knowledge you need to identify and build a simple machine, we are going in to the DESIGN section of our class. Next time, we will learn about designing machines and specifically more about Rube Goldberg machines.

Next time, we will be building our first small machines
• If you have supplies in your classroom to build the machines, you could introduce some of the supplies
• If you do not have all the supplies you need, you could invite students to bring supplies to class. Send an email or note home to parents as well. Examples of supplies include (but are not limited to):
  • Legos or other building blocks
  • Dominoes
  • Cardboard, shoe boxes, packing boxes
  • String
  • Glue
  • Tape
  • Construction paper
  • Scissors
  • Rubber bands
  • Small paper cups
  • Twist ties / chenille stems (pipe cleaners)

Dismiss

CHALLENGE
ADVANCED STUDENTS
• Don’t have examples or photos of catapults, set students together in teams and invite them to invent a catapult or similar machine to launch the puffball.
• Require students to create a compound machine for their catapult.
• Set goals for accuracy, distance, height, and adapt each machine through an iterative process so that students learn which adaptations create different outcomes

SIMPLIFY
FOR LESS ADVANCED STUDENTS
• Have several examples of the simple catapult available for students to look at while they create their own catapults.
• Build a catapult at the same time, walking students through the process one step at a time.
SEASON TWO:
Design Thinking – Planning
Compound Machines

Objectives
Understand the steps in a design thinking cycle, and understand the components of a Rube Goldberg machine and build a multi-step Rube Goldberg machine with a small team.

“I can understand the steps in a Design Thinking process. I am comfortable planning, building and testing a compound machine. I can adapt and adjust my machine based on what I learn during testing, so that it works more effectively or accurately.”

Discuss:
- Who can remember some examples of simple machines – maybe some in this classroom?
- Can anyone name all six machines?

Today, we are going to learn about the DESIGN process, so we can begin to plan and design our Rube Goldberg machine.

Overview of Session Two
Students will learn Design Thinking concepts, plan a compound machine and build and test the machine.

- Welcome & Introductions
- Lesson 2A: What are the steps of the Design Process?
- Activity 2A: Watch video about Design Process and Discuss
- Break
- Lesson 2B: What is a Rube Goldberg Machine?
- Activity 2B: Plan, build and test a small Rube Goldberg Machine
- Consolidation / Clean-up

Review and Transition Thoughts
LAST TIME WE WORKED ON:
- Learning the six simple machines
- Identifying the simple machines in our daily lives
- Understanding the WORK that machines do by applying FORCE and/or creating MOTION
<table>
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<th><strong>VOCABULARY USED IN THIS ACTIVITY</strong></th>
<th>input, trigger, output, result, sequence, requirement</th>
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<td><strong>Craft supplies to build machines</strong> – cardboard, shoeboxes, string, tape, glue, scissors, twisty chenille stems (pipe cleaners), legos, wheels, cups, blocks, balloons, tacks, bells, dominoes, ping pong or golf balls, toy cars, trains, ramps, marbles, playing cards, popsicle sticks, etc.</td>
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<td><strong>Butcher paper and/or large sheets of paper</strong> – for the design process, it works best if students can draw on large paper and/or 11x17 sheets.</td>
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<td><strong>Computer/Screen/Projector</strong> – you will be showing a video at the beginning of this class, ensure that you will have internet access in the classroom area, and secure the required computer/screen or TV/projectors, etc. Also, ensure that you have the proper connection cable and power cords.</td>
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<td><strong>RESOURCES</strong></td>
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<td><strong>Rube Goldberg Machine Examples</strong>:</td>
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</tr>
<tr>
<td></td>
<td>Cover tables/desk groups with butcher paper and draw lines to create four quadrants. OR, use painter’s tape to divide the table in four quadrants and have large sheets of paper (11x17), in each quadrant</td>
</tr>
<tr>
<td><strong>BACKGROUND KNOWLEDGE</strong></td>
<td>Students will need the knowledge from Session One: Simple Machines.</td>
</tr>
</tbody>
</table>
LESSON 2A

**Timing:** 45 minutes (expand or compress as needed for your class schedule)

**DISCUSS**

15 minutes

*Worksheet 2A: Design Thinking: The Launch Process.* A teacher’s version is included.

**VIDEO:** Show the Design Thinking Video: *The Launch Cycle: A Design Thinking Framework for K-12 Students*

Students should complete the worksheet while they are watching the video.

**ASK:** Talk about each step in the Launch process, incorporating examples that are relevant to the process of designing a simple version of a Rube Goldberg machine.

**DISCUSS:**

- **Look, Listen and Learn** – observe the simple machines in the room, listen to your teammates talk about the machines they would like to incorporate into their design, and think about what we have learned about simple machines.

- **Ask Questions** – think “what if...” and “How would we...” the goal is to understand what their team is excited about and also to understand the tools/supplies they have access to. Talk about how to turn what they learn in to ideas for their machine.

- **Understand the problem/challenge** – When you are solving a problem, how do you make sure you truly understand all the components of the problem?

- **Navigate Ideas** generate ideas. What does it mean to brainstorm? Is it better to have a lot of ideas or just a few? Do you “throw out” ideas?

- **Create a Prototype** – talk about the importance of starting with your initial ideas and then building a “first draft” of their machine. Discuss what it’s like to put a lot of ideas on the table, and then choose only a few. How open are they to changing their design?

- **Highlight What Works and Fix What’s Failing** – Focus on iteration – lots of changes can be a very good thing.

**EXPLORE**

30 minutes

**What is a Rube Goldberg Machine?**

Rube Goldberg was a cartoonist who was famous for his goofy illustrations of people that build VERY COMPLEX machines to do VERY SIMPLE tasks. (Show a couple examples of his cartoons – you can find them at: RubeGoldberg.com)

Use the videos in the resource section to show examples of Rube Goldberg machines. Show one simple and one complex example of a Rube Goldberg machine so kids have ideas in their minds.

We also recommend showing one of the videos with lots of RGM ideas to get the kids thinking about the different TRIGGERS and OUTCOMES that they might create with the materials you have on hand.

**Supplies:** The large sheet of paper and/or butcher paper, painter’s tape, pencils.

We definitely want to use pencils for this exercise so students get the idea that they are creating drafts and ideas.

**EXPLORE**

**STEP ONE**

Start as a team by deciding what you want your machine to do. Some ideas:

- Push a car forward over a finish line
- Knock over a cup
- Roll a ball off the table, or in to a box
- Turn the page in a book

Have teams look at all the supplies they have and encourage them to come up with a least three ideas for the finale on their machine.
LESSON 2A (CONTINUED)

STEP TWO
Design four steps to achieve the goal upon which the team agrees. Use the quadrant boxes set out on the table to represent steps one through four. Invite the students to brainstorm a few ideas for each step, then they can return to their ideas and prioritize. Have them draw a picture, or write a description in each of the quadrants for the machine they will build for that step. (NOTE: the machines they build after the break do not necessarily have to go through those four quadrants – they could be linear, or circular, etc.)

Words to discuss:
• **Input** – what force or activity sets the machine in motion. Remind them that human force can start the machine at the very beginning, but we can’t touch it after that.
• **Trigger** – what triggers each step after the human intervention to get the machine started.
• **Sequence** – the idea that each force leads to a subsequent force, and they need to go in a particular order
• **The Requirements** – what are your requirements. For a Rube Goldberg competition, the requirements might include levels of sound, length of time for the machine to execute, a starting and stopping point, etc.

REFLECTION
Facilitation question ideas:
• Thinking about the “Launch” process (Design thinking), is there one step or process that’s more important than the others? Why?
• Now that you’ve thought about your four steps for the machine you’re going to build, is there one step that’s harder or easier than the others?
• What order will you build them in?
• Do you have a plan for the building process?

TRANSITION
Now we’ll be taking a break for 15 minutes, when we come back, we’ll actually be building the machine that you just designed. We’ll spend time testing it, and making changes based on what we learn. By the end of class – you’ll have a working Rube Goldberg Machine!

SIMPLIFY
FOR LESS ADVANCED STUDENTS
• Determine the end ahead of time – so every team must, for example, roll the ball off the desk as the finale.
• Give them pre-determined activities, but let each team determine the order and exactly what that step looks like – for example, the four required steps could be:
  • Roll a toy car across the table
  • Domino chain reaction
  • Pull a string
  • Release the ball and the ball rolls down a ramp and off the table

CHALLENGE
ADVANCED STUDENTS
• Add more steps – older or more advanced students might be able to design six or eight steps in the same time
• Give the team some parameters – require them to use dominoes in at least one step, or require them to use all six simple machines in their finished machine
LESSON 2B

Timing: 1 hour (expand and contract as needed)

Build the Rube Goldberg machine that they designed in the first half of the Session.

DISCUSS

ASK:

• Do you think your machine will work perfectly on the first try?
• Is it better to get it perfect, or to build the machine and test it and then make changes?
• Is it OK to change your design?

DISCUSS: Encourage discussion that focuses on the importance of testing and iteration. The Design Thinking process (in our LAUNCH version used here), drives innovation and creativity through the iteration and adaptation phase. Help kids learn GRIT, PERSEVERENCE, and have fun, but creating an environment in which it’s OK to try a few things and make changes.

EXPLORE

Invite the students to collect the supplies they need to build the four stages (or more), of the machines that they designed. Encourage them to work together as a team to build the machine, and start testing it.

Set a specific time limit (we suggest 15 minutes), for the first attempt at a dry run through the stages that they’ve completed so far. Then encourage them to make adjustments. You might invite the teams to do a little reflection on how they are working together

• Is everyone contributing?
• How are your organizing the work that needs to get done
• Does anyone feel frustrated? Left out?

Return to building. When there are about 25 minutes left in the class, stop the work and invite each team to do a “Gallery Walk” and see the other team’s machines, have each team run through their machine and describe the steps and then execute – see if they all work. Move quickly through this “exhibition” section and ensure that positive comments are being made about the machines that work, and those that don’t work.

Give everyone 5 more minutes to make adjustments and then do a grand finale attempt on each machine.

REFLECT

Facilitation question ideas:

• What about your team worked well?
• What didn’t work?
• What changes did you make to your machine after you tried a couple test runs?

TRANSITION TO CLOSE

We’ve learned a lot about the design process, and about Rube Goldberg machines. Next time, we will be designing our final project.

Your homework:

• Watch a few more Rube Goldberg videos (with your parent’s supervision) to get more ideas
• Start thinking about the triggers and outcomes you want to create
• Find supplies around your house that we could use in the final machine and bring them in, please don’t bring in anything that is sentimental or valuable
• Draw some pictures or write your ideas down and bring your notes with you next time
SESSION THREE:
Planning our Rube Goldberg Machine

Objectives

Emphasize that design is an iterative process and gain understanding that creativity can be revised in a design process to better meet user needs, functional goals, criteria. Practice understanding criteria and constraints.

“I can initiate the design process and use a stepwise process more than once, name the steps, and use iteration to learn from things that don’t immediately work.”

Review and Transition Thoughts

LAST TIME WE WORKED ON:

• Learned the design thinking process
• Learned about Rube Goldberg and a Rube Goldberg machine
• Built a compound machine that utilizes several different simple machines to accomplish a task

DISCUSS:

• Can anyone recall who Rube Goldberg was?
• What is a Rube Goldberg machine? What makes it unique? Why do you think they are (or are not) funny?

• What are some of the steps in the design thinking or “Launch” cycle?

Today, we are going to take what we learned about designing and planning and we’ll begin to work on our final Rube Goldberg Machines.

Overview of Session Three

Students will learn Design Thinking concepts, plan a compound machine and build and test the machine.

• Welcome & Introductions
• Lesson 3A: Begin with the end in mind.
• Activity 3A: Work backwards to design the steps in your machine
• Break
• Lesson 3B: Review your machine and plan supplies
• Activity 3B: Prototype one or two sections of your machine, test and iterate
• Consolidation / Clean-up
| VOCABULARY USED IN THIS ACTIVITY | process, sequence, iterate, prototype, ideate, criteria, requirements, constraints, limits.  
RGM = Rube Goldberg Machine |
| TIME NEEDED | 2 hours (timing included in the lesson plan is based on 2 hours, you could make the lesson longer or shorter to suit your needs) |
| MATERIALS AND SUPPLIES | Nametags / Table Tents – A way for students to write their name and for it to be visible for the instructor throughout the first lesson  
Craft supplies to build machines – cardboard, shoeboxes, string, tape, glue, scissors, twisty chenille stems (pipe cleaners), legos, wheels, cups, blocks, balloons, tacks, bells, dominos, ping pong or golf balls, toy cars, trains, ramps, marbles, playing cards, popsicle sticks, etc.  
Worksheets – one copy for each student printed ahead of time  
Pencils, extra paper – since this session is about design, it’s a good idea to have some large sheets of paper on which teams can draw their ideas  
Butcher paper and/or large sheets of paper – for the design process, it works best if students can draw on large paper and/or 11x17 sheets.  
Computer / Screen / Projector – you will be showing a video at the beginning of this class, ensure that you will have internet access in the classroom area, and secure the required computer/screen or TV/projectors, etc.  
Also, ensure that you have the proper connection cable and power cords.  
NOTE: if you are competing in the MakerBolder Community Rube Goldberg Challenge, you should have your “in ramp” and “out ramp” and golf ball incorporated into the design, along with the guidelines for the Rube Goldberg challenge, which can be found on the MakerBolder website. |
| RESOURCES | These resources were provided for Session Two. They include the LAUNCH cycle (design thinking), as well as resources for fun ideas for Rube Goldberg mechanisms.  
Design Thinking Video: [The Launch Cycle: A Design Thinking Framework for K-12 Students](#)  
Rube Goldberg Machine Examples:  
OK Go [This Too Shall Pass](#) (fun music video that shows a long string of Rube Goldberg connections, appropriate for children). For bonus points, have kids identify what types of simple machines are used throughout the video  
[Rube Goldberg Ideas](#) (a 4+ minute video with a lot of simple ideas for Rube Goldberg mechanisms)  
[75 Rube Goldberg Ideas and Inventions](#) (another 4+ minute video with 75 ideas for components of a Rube Goldberg machine) |
| SET-UP AND PREPARATION | Read through lesson and adapt stories / materials from your experience  
Pre-screen any videos or audio materials you intend to use  
Build a sample Rube Goldberg, if you would like – something very simple with only 3 or 4 steps  
Print worksheets  
Cover tables / desk groups and protect classroom areas as needed  
NOTE: if you are competing in the MakerBolder Rube Goldberg Challenge, you’ll want to prepare the guidelines for the final machines ahead of time and make sure you are familiar with the constraints so you can guide team design(s) |
| BACKGROUND KNOWLEDGE | Students will need the knowledge from Sessions One and Two. |
**LESSON 3A**

**Timing:** 45 minutes (expand or compress as needed for your class schedule)

**DISCUSS**

15 minutes

**Worksheet 3A: Begin with the End in Mind**

**NOTE:** If you are designing a machine for the MakerBolder Community Rube Goldberg Challenge, please provide your students with the required starting and ending points per the Guidelines on the MakerBolder website.

If you are not creating a community machine, the sky is the limit! Here are some fun ideas for simple tasks that your team might choose:

- wipe your mouth
- push a car into a shoebox
- turn a page
- drop a bottle into trash
- push a button
- plant a seed
- turn off an alarm
- fill a glass
- capture a monster

**ASK:** What would you like your machine to do?

**DISCUSS:** Each person should come up with two or three ideas for the conclusion of the machine, then the teams should discuss all the ideas and narrow their choices to one final idea.

**ASK:** Now that you know what your machine will do, can you think of a few different types of simple machines that you could use to create the desired goal?

**DISCUSS:** Invite the participants to plan two or three different machines that could accomplish the end goal. The worksheet includes space for each participant to draw a couple fun ideas for the end of their machine.

After the team has discussed everyone’s ideas, invite participants to turn the worksheet over to draw and describe the final choice.

**EXPLORE**

30 minutes

To help with their planning, invite participants to “play” with building materials, craft supplies, etc. to help them illustrate their ideas to their teammates.

Revisit the idea of iterating on their designs – the end design should be the result of testing, conversation, ideation, and creating.

At the conclusion of Lesson One, each team should have a clear understanding of the criterion and any restrictions or guidelines they must follow, as well as a clear starting point for the final step in their machine.

Remember these words from Session Two and challenge each team to consider these components in their ending mechanism:

- Input
- Trigger
- Sequence
- Requirements

**REFLECT**

Facilitation question ideas:

- How did it work for you to generate a bunch of ideas, and then narrow the ideas down to a few to use?
- Was there overlap between some of your ideas?
- How are you making sure that everyone is participating and being heard?

**TRANSITION**

Now we’ll be taking a break for 15 minutes, when we come back, we’ll move in to designing the rest of our machine. Your team will be planning the mechanisms from start to finish based on the requirements we discussed!

**CHALLENGE ADVANCED STUDENTS**

- Introduce more challenging criteria (i.e. must use a robot, or must include every simple machine)

**SIMPLIFY FOR LESS ADVANCED STUDENTS**

- Demonstrate a few possible ways to accomplish the task
- Give every team the same final task
- Suggest a trigger or the supplies that they might use so their choices are more limited
LESSON 3B

Timing: 1 hour (expand and contract as needed)

DISCUSS

ASK: Do you remember the stages in the LAUNCH cycle?

- Look, Listen and Learn – observe the simple machines in the room, listen to your teammates talk about the machines they would like to incorporate into their design, and think about what we have learned about simple machines
- Ask Questions – think "what if..." and "How would we..." the goal is to understand what their team is excited about and also to understand the tools/supplies they have access to. Talk about how to turn what they learn in to ideas for their machine.
- Understand the problem/challenge – When you are solving a problem, how do you make sure you truly understand all the components of the problem?
- Navigate Ideas, generate ideas. What does it mean to brainstorm? Is it better to have a lot of ideas or just a few? Do you “throw out” ideas?
- Create a Prototype – talk about the importance of starting with your initial ideas and then building a “first draft” of their machine. Discuss what it’s like to put a lot of ideas on the table, and then choose only a few. How open are they to changing their design?
- Highlight What Works and Fix What’s Failing – Focus on iteration – lots of changes can be a very good thing.

We are now going to plan the remaining steps in your Rube Goldberg Machine. We are squarely in Steps One through Four. We’ll create a full prototype next time and the following time, but this time we are focusing on LISTENING to each other, asking great QUESTIONS, understanding our CONSTRAINTS, and creating IDEAS that we can test.

ASK: Does anyone on your team have additional guidelines or goals they’d like to discuss with the team?

(Perhaps someone wants to make sure that they use a particular tool or toy in the machine? Or they want to make it extra challenging by adding more steps than any other team? Give the teams a moment to explore the question.)

EXPLORE

Supplies:

- Worksheet 3B: Putting it all Together – Planning the Whole Machine
- Materials: Craft supplies, tools, etc. so the team(s) can fiddle, play and demonstrate their ideas as they are planning

NOTE: The teams will not be building their entire machine this time – the majority of the building will happen next time. Encourage the team(s) to “tinker” and utilize the materials to think through ideas, rather than to actually build something that they will use in the final machine.

To encourage the idea of iteration and ideation, you might consider supplying only tools and supplies such as popsicle sticks, or Legos – materials that they won’t actually use at all in their final machine, but that allow for rapid iterations.

EXPLORE

Utilizing the worksheet provided – write down your final goal on the line provided, and then think about all the different triggers, simple machines, actions, movements, etc. that you might want to incorporate. Think about the supplies or materials you might want to use.

PART ONE:

Work together with the group to get as many ideas out to the team as possible. The goal is volume of ideas. Teams should be looking and listening, and asking questions.

PART TWO:

Narrow all the ideas down to a few that the team is most excited about and begin to think about the way you could string those ideas together. Ask more great questions.

- How could one machine trigger the action in the next machine?
- Can we get the supplies we need to create the steps we like the best? Where might we need to compromise?
- Revisit the guidelines and requirements – do any of the ideas violate the requirements? (Understand the challenge/problem)
- Abandon ideas that won’t work, and highlight ideas that have the best chance of succeeding (Navigate the ideas)
PART THREE:
Worksheet 3C: Sequence Planning and Supplies

EXPLORE
Transition the teams to the final planning steps before they begin to prototype.
- Ask each team to draw / list their steps in the specific order that they intend to use for their first prototype next session.
- Invite the teams to create a supply list for the materials they need to bring in to complete the steps of the machine

Exposition
Invite each team to select a representative (or more than one), to describe their machine from end-to-end, and review their supplies list. The presentations should be brief and fun.

REFLECT
Facilitation question ideas:
- What about your team worked well?
- What didn’t work?
- What changes did you make to your machine after you explored more ideas?
- What are you worried about for next Session?
- What are you the most excited about regarding your machine?

TRANSITION TO CLOSE
We’ve learned a lot about the design process, and about Rube Goldberg machines. We’ve designed an end-to-end Rube Goldberg machine and even fiddled with some of the ideas that we have in our plan. Next time, we’ll convert our ideas to an actual Machine! We’ll get to building and testing our ideas to see if we need to make any changes.
Remember, iteration (making changes), is part of the fun of inventing. So don’t get to set in your ways, and come prepared to have fun and to make adjustments.

Your homework for the time:
- Bring the supplies that your team needs to complete the project
- Finish the descriptions and/or drawings for each step of the machine.

CHALLENGE
ADVANCED STUDENTS
- Ensure that every team has a complete illustration AND description of each step – even if the illustrations are crude, they are an important part of planning and identifying the needed supplies
- Invite students to take an inventory of every simple machine they use, list the trigger and action/motion for each step, etc.

SIMPLIFY
FOR LESS ADVANCED STUDENTS
- Create a sequence for the students. Instead of inviting them to plan from scratch, ask them to describe the steps in the machine you built and think about what they might change (for example, make the inclined plan taller, or a wheel smaller, etc)
- Create a list of potential triggers, action/motion, etc, and invite the students to choose three or four, rather than creating the ideas on their own
SESSION FOUR: Make Your Machine Draft One – Build and Test

Objectives
Students will work together to translate their designs from Session Three, into the working Rube Goldberg machine. Students will assign roles and responsibilities and work together to build and test their machine.

“I can work with my team to make a Rube Goldberg Machine (RGM) that works. I can apply and combine my knowledge of simple machines, cause and effect, design process and Rube Goldberg machines to participate in creating an RGM that is consistent, meets criteria, and adheres to constraints.”

Review and Transition Thoughts
LAST TIME WE WORKED ON:
- Planning our machines using the LAUNCH process (design thinking)
- Generating a volume of ideas for our machine and then narrowing our ideas to a plan
- Understanding how the steps our machine will take, what the triggers and actions are, and the supplies we would need to build the machine

DISCUSS:
- Have you changed your mind about anything in your design? Take a moment as a team to revisit your plan, and discuss any areas where you have concerns or think you should make changes.
- Double check your supply lists, and the supplies you actually have. Make adjustments as needed if supplies are missing.

Today, we will build the first draft of our machines. We will also spend a little time talking about your presentation to your parents (the judges if you are entering a Rube Goldberg Challenge).

Overview of Session Four
Students will learn Design Thinking concepts, plan a compound machine and build and test the machine.

- Welcome & Introductions
- Lesson 4A: Create team roles and clarify activities to build
- Activity 4A: Build the first iteration of your machine
- Break
- Lesson 4B: Outline a presentation about your machine
- Activity 4B: Test and iterate your machine, capture lessons learned in your presentation
- Consolidation / Clean-up
<table>
<thead>
<tr>
<th><strong>VOCABULARY USED IN THIS ACTIVITY</strong></th>
<th>action, sequence, Rube Goldberg Machine = RGM, consistency, reliability, re-set, criteria, constraint, roles and responsibilities</th>
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<td><strong>TIME NEEDED</strong></td>
<td>2 hours (timing included in the lesson plan is based on 2 hours, you could make the lesson longer or shorter to suit your needs)</td>
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| **MATERIALS AND SUPPLIES**          | **Nametags / Table Tents** – A way for students to write their name and for it to be visible for the instructor throughout the first lesson  
**Craft supplies to build machines** – cardboard, shoeboxes, string, tape, glue, scissors, twisty chenille stems (pipe cleaners), legos, wheels, cups, blocks, balloons, tacks, bells, dominoes, ping pong or golf balls, toy cars, trains, ramps, marbles, playing cards, popsicle sticks, etc.  
**Worksheets** – one copy for each student printed ahead of time  
**Pencils, extra paper** – since this session is about design, it’s a good idea to have some large sheets of paper on which teams can draw their ideas  
**NOTE:** if you are competing in the MakerBolder Community Rube Goldberg Challenge, you should understand the judging criteria for the team interview portion of the challenge. Visit [MakerBolder website](http://www.makerbolder.com) for more information. |
| **RESOURCES**                       | Revisit videos and resources from prior lessons. Replay videos with ideas, etc. as needed |
| **SET-UP AND PREPARATION**          | Read through lesson and adapt stories / materials from your experience  
Print worksheets  
Group desks to make it easier to work in teams. If your classroom has table, set chairs around the tables so it will be easy to form several teams when students arrive  
Prepare the workspace, tools and supplies for safety and protect any materials in the classroom that should not be used or damaged |
| **BACKGROUND KNOWLEDGE**            | Students will need the knowledge from Sessions One, Two and Three as well as their design plan from which to build their machine. |
LESSON 4A

**Timing:** 90 minutes (less or more based on the total time of your session)

**DISCUSS**

15 minutes

**Worksheet 4A: Team Assignments**

You have a big task in front of you – your machine has multiple steps that need to get built, and each of your team members have different talents, and desires.

**ASK:** As a team, explore what you each like to do, and also capture all the tasks that need to get done.

**DISCUSS:** Some members of the team may need to do things they don’t like in order to complete all the tasks. Some might also need help to complete their tasks. Quickly outline what needs to get done, and decide who will be doing each part of the project.

**EXPLORE**

**BUILD!**

Now your team should go to work building and implementing the plan you created.

**REFLECT**

As you are building, take a break every 15 to 20 minutes to invite the teams to reflect on:

- What’s working and what’s not working?
- Is everyone playing the role they were assigned?
- Is there work that needs to get done that wasn’t accounted for in the original Team Assignments Worksheet?
- What adjustments do you need to make

**TRANSITION**

At an appropriate time, invite the teams to take a break and have a snack, then return to building.

**CHALLENGE**

ADVANCED STUDENTS

- Invite the teams to create job titles for each member of the team
- Assign a project manager to oversee the project
- Assign a “scribe” to document important steps along the way

**SIMPLIFY**

FOR LESS ADVANCED STUDENTS

- Spell out the steps and/or roles and tasks and invite the teams to simply “sign up” for the tasks
**LESSON 4B**

**Timing:** 30 minutes (expand and contract as needed)

**DISCUSS**

**ASK:** Invite the teams to reflect on the build process for the day. *How did their team work together? Did they get as much done as they had hoped? Is the machine working? Why or why not?*

**ASK:** *What have they changed in their machine as a result of lessons learned? Testing?*

**EXPLORE**

Each team will be invited to present a brief overview of their process and then demonstrate their machine to their parents or to the judges (if you are entering a judged challenge).

Review the criterion with students (if applicable), and invite them to reflect and plan their presentation. They should identify the role each person on the team will play, and the material they want to convey.

For the MakerBolder.com Rube Goldberg Challenge, follow the guidelines provided in the material on the MakerBolder.com website.

Invite each team to write an outline for their presentation, assign roles and practice their presentation. They can use notebook paper or blank papers to complete their planning for the presentation.

**EXPOSITION**

Have each team present their machine to the other teams and demonstrate how it works and what they will be focusing on in Session Five.

**REFLECT**

**Facilitation question ideas:**

- How did your team roles work? Do adjustments need to be made?
- What is left to do next time? Prioritize the activities you need to complete.

**TRANSITION TO CLOSE**

Session Five focuses on completing your machine, testing it several times to make sure everything works, finalizing your presentation, and then presenting your final machine to your parents as a way to practice your presentation and reflect on your learning.

**HOMEWORK**

Practice your portion of the presentation.

If needed, think of ways to solve any problems that you are having in your team dynamic, in the way your machine is working, and/or in the way you are getting work done.

**CHALLENGE ADVANCED STUDENTS**

- Give very little guidance for the presentation and let the team develop an engaging presentation. Invite them to do a dry run or two and provide feedback to help them improve it based on the judging criterion provided.

**SIMPLIFY FOR LESS ADVANCED STUDENTS**

- Assign roles based on observed strengths for each of the children. Ensure that each child has a role to play in the presentation, if needed, the roles could include simple things like pointing to parts on the machine, or triggering the initial action.
SESSION FIVE: Make Your Machine Draft Two – Test and Iterate

Objectives

Students will work together to finalize their presentations and do the final testing and building on their machines.

“I can work with my team to solve the remaining few challenges (sometimes the toughest challenges), and complete our machine within the time allowed. I can plan and present a coherent story about my Rube Goldberg Machine class and the machine itself.”

Review and Transition Thoughts

LAST TIME WE WORKED ON:

• Assigning roles and tasks to team members
• Building our machines and testing them
• Planning our presentation

DISCUSS:

• Have you changed your mind about anything in your design? What about your team roles? Or the tasks that need to be completed?

Today, we will build the final machines. We will also spend a little time finalizing your presentation to your parents (the judges if you are entering a Rube Goldberg Challenge).

Overview of Session Five

Students will learn Design Thinking concepts, plan a compound machine and build and test the machine.

• Welcome & Introductions
• Activity 5A: Continue building, testing and iterating the machine
• Break
• Activity 5B: Finalize the presentation
• Presentation
• Celebration and cleanup
<table>
<thead>
<tr>
<th>VOCABULARY USED IN THIS ACTIVITY</th>
<th>No new vocabulary</th>
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<tbody>
<tr>
<td>TIME NEEDED</td>
<td>2 hours (timing included in the lesson plan is based on 2 hours, you could make the lesson longer or shorter to suit your needs)</td>
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</table>
| MATERIALS AND SUPPLIES           | Nametags / Table Tents – A way for students to write their name and for it to be visible for the instructor throughout the first lesson  
Craft supplies to build machines – cardboard, shoeboxes, string, tape, glue, scissors, twisty chenille stems (pipe cleaners), legos, wheels, cups, blocks, balloons, tacks, bells, dominoes, ping pong or golf balls, toy cars, trains, ramps, marbles, playing cards, popsicle sticks, etc.  
Worksheets – No worksheets for this session  
Pencils, extra paper – since this session is about design, it’s a good idea to have some large sheets of paper on which teams can draw their ideas  
Projector or other presentation tools, if applicable. |
| RESOURCES                        | Revisit videos and resources from prior lessons. Replay videos with ideas, etc. as needed |
| SET-UP AND PREPARATION           | Prepare the workspace, tools and supplies for safety and protect any materials in the classroom that should not be used or damaged  
Prepare the presentation area and any supplies, tools, etc. needed for the final presentations |
| BACKGROUND KNOWLEDGE             | Students will need the knowledge from Sessions One, Two, Three as well as their design plan from which to build their machine. |
LESSON 5A

Timing: 75 minutes (less or more based on the total time of your session)

BUILD! TEST! ITERATE!
Let the teams dive in to building the remaining sections of their machine, testing their machine, and making changes as needed.
As you are building, take a break occasionally to invite the teams to reflect on:
• Are you seeing things differently today than in the last Session?
• What new things might you incorporate into the story you tell in your presentation?

BREAK
At an appropriate time, invite the teams to take a break and have a snack, then return to building.

Prepare Presentations
Timing: 30 minutes (expand and contract as needed)

DISCUSS
Invite the teams to explore the outline they created the day before. They should make changes based on the construction work done today, and any lessons they learned or thought about between Sessions.
Ask the teams to practice their presentation at least once.

EXPLORE
Invite parents to attend the last 15 minutes of the class during which time the team(s) will make their presentations and then demonstrate their Rube Goldberg Machine.
Invite parents to ask questions and/or provide feedback about what they liked and what they would improve.
It can sometimes be helpful to prompt parents with great questions that students will feel comfortable answering. You can write these on index cards, or hand out a small paper with some ideas on it. Thought starters might include:
• What is a Rube Goldberg Machine? Who was Rube Goldberg?
• What simple machines are included in your Rube Goldberg Machine?
• Why did you pick this task for your machine?
• What role did your play on your team? (question for after the class)

TRANSITION TO CLOSE
Thank you to parents and any other acknowledgements that are needed.
Invite families to assist with cleanup.
Request session evaluations, if appropriate.
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