RUBE GOLDBERG IN THE 21ST CENTURY

TEACHER'S GUIDE

Genesis Learning

Empower your students to imagine something into existence.

Contents

What Good Problem Solvers Do

TAKE TIME TO CAREFULLY DEFINE A PROBLEM…

Ineffective problem solvers are sometimes led astray because they make incorrect assumptions about what a problem requires. An effective problem solver will take the time to ensure that she understands the problem and what it is requiring her to do. She will be able to clearly state the problem in terms of what is known and what is unknown. She will be able to articulate the relationship of resources involved in a problem.

KNOW WHAT THEY KNOW...

Good problem solvers perform an inventory of what they already know and incorporate that knowledge into their understanding of the current problem. This is done both in terms of understanding the shortcomings of an existing system as well as designing a solution or improvement to that system. Effective problem solvers engage existing knowledge across disciplines and in novel situations.

FIGURE OUT WHAT THEY NEED TO KNOW...

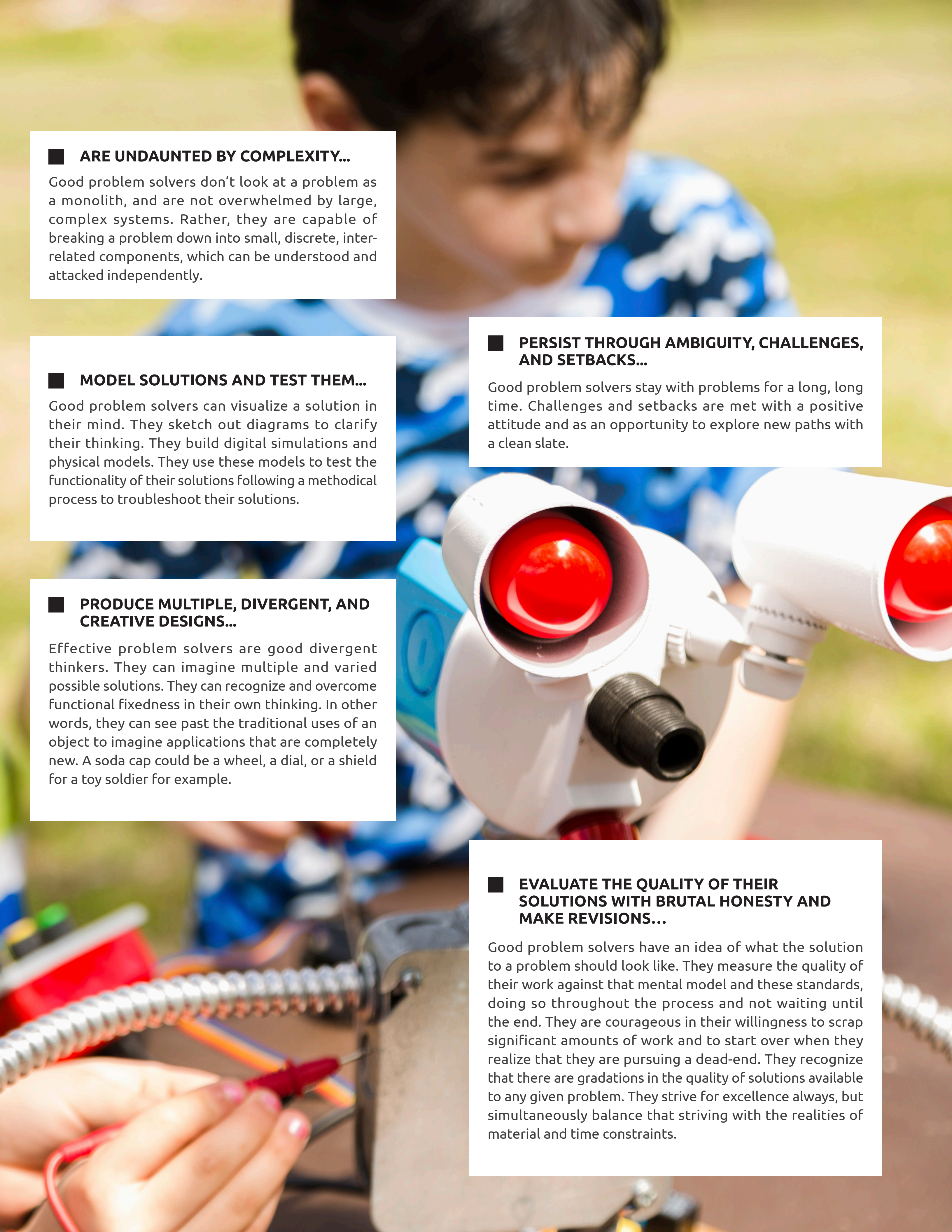
Good problem solvers can identify gaps in their own understanding, and articulate those gaps in the form of questions. Such questions include both over-arching questions that get to the solution of a particular problem (how can I design an alarm system that uses a laser beam as a trigger?) as well as more tactical, informational questions (what does a pull-down resistor do, and why are they important in a circuit that uses digital logic? Good problem solvers are constantly asking themselves, “What don’t I understand about this system, and what do I need to learn in order to understand it better?) Good problem solvers recognize when their existing schema and mental models must be updated, revised or abandoned.

EFFECTIVELY AND EFFICIENTLY FIND THE INFORMATION THEY NEED...

Good problem solvers are expert researchers. They are well versed and comfortable using all manner of information resources (including classmates). Not only are they able to distinguish between reliable and unreliable sources, but they can also identify high quality sources that are understandable at their reading level.

COLLABORATE...

Good problem solvers view teammates as sources of information and talent. They help teammates to divide tasks equitably and according to one another’s strengths. Good problem solvers help their team to work through conflict and to value the contributions of all team members.



ARE UNDAUNTED BY COMPLEXITY...

Good problem solvers don't look at a problem as a monolith, and are not overwhelmed by large, complex systems. Rather, they are capable of breaking a problem down into small, discrete, inter-related components, which can be understood and attacked independently.

MODEL SOLUTIONS AND TEST THEM...

Good problem solvers can visualize a solution in their mind. They sketch out diagrams to clarify their thinking. They build digital simulations and physical models. They use these models to test the functionality of their solutions following a methodical process to troubleshoot their solutions.

PRODUCE MULTIPLE, DIVERGENT, AND CREATIVE DESIGNS...

Effective problem solvers are good divergent thinkers. They can imagine multiple and varied possible solutions. They can recognize and overcome functional fixedness in their own thinking. In other words, they can see past the traditional uses of an object to imagine applications that are completely new. A soda cap could be a wheel, a dial, or a shield for a toy soldier for example.

PERSIST THROUGH AMBIGUITY, CHALLENGES, AND SETBACKS...

Good problem solvers stay with problems for a long, long time. Challenges and setbacks are met with a positive attitude and as an opportunity to explore new paths with a clean slate.

EVALUATE THE QUALITY OF THEIR SOLUTIONS WITH BRUTAL HONESTY AND MAKE REVISIONS...

Good problem solvers have an idea of what the solution to a problem should look like. They measure the quality of their work against that mental model and these standards, doing so throughout the process and not waiting until the end. They are courageous in their willingness to scrap significant amounts of work and to start over when they realize that they are pursuing a dead-end. They recognize that there are gradations in the quality of solutions available to any given problem. They strive for excellence always, but simultaneously balance that striving with the realities of material and time constraints.

Introduction

Thank you for your interest in the BareBones series of STEAM kits. We at Genesis Learning are passionate about learning through doing and creating an authentic context in which students can build a deep understanding of any topic. These kits allow them to explore concepts such as electricity, digital logic, and computer programming.

Most importantly, students will learn that their imagination combined with persistence and curiosity can be a powerful tool. They will learn not to be intimidated by complexity, and that with a little patience, they can understand and invent sophisticated electronic devices.

We embrace a project-based learning approach, and our designs draw on current research regarding student motivation and student-centered learning. We believe that given a meaningful and interesting problem, students can be self-sufficient learners and problem solvers.

Our primary goal is for our students to *learn how to learn.*

Throughout the process, instructors should model good problem solving and research strategies. As instructors, we are the role models for the habits of mind we seek to instill in our students.

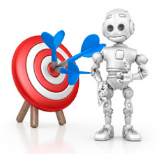
This Teacher's Guide includes an outline for introducing each of the following three projects:

Rube Goldberg in the 21st Century — Students will apply their knowledge of simple machines to the design and construction of an original Rube Goldberg invention. They will add digital functionality to their creations by integrating and programming a Makey Makey device.

The guide also includes a suggested schedule of the topics associated with each project.

HOW TO USE THIS TEACHERS GUIDE

OBJECTIVES



Drawing on the work of Grant Wiggins and Jay McTighe, we begin each project by defining exactly what it is that we want students to understand and what would serve as evidence of that understanding. Each project has a chart that lists these understandings and associated evidence.

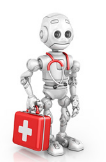
The chart is divided into sections for one or two “Enduring Understandings,” things that are “Important to Know and Do,” and a few things that are “nice to be familiar with.”

Many curricula mistakenly put the focus on things that are “important to know and do” and consequently fail to highlight the “Enduring Understanding.” The Enduring Understanding should really be the point of the project, for it is this understanding that gives context to all of the other work that students will do. This is what you would expect your students to remember twenty years after the project.

While it is important for students to know how to connect an LED into a circuit, if they don’t remember which leg is the anode leg after the project is over, I think most of us would be okay with that.

Download Chronicle App
Teachers may find it helpful to use the ipad app Chronicle to track student mastery of important skills as well as to capture video, photo, and audio artifacts along with my own observational notes as I walk around the class.

CHECKING FOR UNDERSTANDING



When kids get confused and fall behind, they check out. It is critically important to do ongoing formative assessment to ensure that students remain engaged and interested and continue to develop the skills necessary to successfully complete their project.

This must be done for the whole class after large group instruction, to determine if a topic needs to be re-taught, but it also has to be done for individual students since many of them will be working through different challenges and require different skills.

Large group understanding checks can be done with simple low-tech techniques such as “fist-to-five” where students hold up five fingers if they understand completely or a fist if they understand nothing at all. Apps like Socrative can also be used to do online polling and instantly get detailed results of what students understand.

When working with individual students, teachers should make time to sit individually with students to review their progress. Individual student surveys can be used to gather information about student interests and prior knowledge on a topic.

The best form of checking for understanding, however, is when students do it themselves. Projects that have Student Guides include a chart called **Check Your Understanding**. Teachers should be sure to reserve class time regularly to have students add questions or problems to this list and to check things off as they get answers.

PROJECT LAUNCH

At the start of each project, there should be some sort of “entry event,” which gets students interested and spells out the objective of the project. These sometimes are as simple as showing a video or an example of the finished product. Other times, however, they can be dramatic. Entry events should lead into a student discussion or brainstorm about what “excellence” looks like in the context of the project.

MINI-LESSONS

These are short, 10 minute lessons designed to deliver essential information to the entire class. Lots of teachers struggle to keep these to less than 10 minutes. Accept the fact that none of us is as interesting as we think we are, and unless we have recently appeared on a reality TV show, or sing in a rock band, we are going to lose most of our kids after 10 minutes. Discipline yourself to trim this information down to ONLY what they absolutely need to know to get through the day and keep it under 10 minutes.

PROTOTYPE AND REVISE

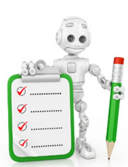
There are numerous things that students will need to prototype for this project before their final product build. What is the best way to mount their servos to the sculpture material? What is the best way to create holes for servo heads in the sculpture material? How can wires be routed neatly and securely? How can items be connected to the blade of the servo? Take time to have students review the standards that they should have written for themselves in their handbook. Build in some time for students to give each other feedback and to make ideas for revision based on their standards.

SHOW WHAT YOU KNOW

A project can gain authenticity when it is published beyond the class. This can be done by posting pictures on a class blog, or by displaying student work in the library. The motivation to make a classmate say, “Wow, that’s cool” is hundreds of times more powerful than the motivation provided by a teacher’s grade on a report card. In all cases, we must be careful that the documentation/publication of a project is not so combersome that it detracts from the actual building.

HOW TO USE THE STUDENT GUIDE

If your kit includes a student guide, the following sections appear throughout to help guide student progress.



Project Checklist — This chart lists each of the challenges and tasks where applicable in the project. Students should check off items when they are complete each day.

Checking Your Understanding — Each project in the student guide has a chart where students should record questions or problems that they have each day. As they resolve these issues, they should check off the “I’ve got it now” box in the chart.

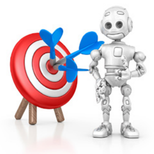
Getting More Information — Each project also includes a collection of research resources that students can use to learn more about a topic they are struggling with.

Parts List

WHAT'S IN THE KIT	SCHOOL-SUPPLIED MATERIALS
Makey Makey Devices (5)	- Chromebook, PC, or Mac - iPad - for Filming - Tools (Suggested) - Hot Glue Guns - Something to Cut Cardboard (box cutter or Exacto knife or MakeDo saw for younger students) - Recycled materials: - Cardboard - Paper Towel /Toilet Paper Rolls - Plastic bottles - Bottle Caps - Egg Cartons - Packing Materials - Soda Bottles - Miscellaneous Crafting Materials: - Electrical Tape - Duct Tape - Masking Tape - Aluminum Foil, Plastic Wrap - String - Brass Fasteners - Thumb Tacks - Pipe Cleaners - Straws - Popsicle Sticks / Tongue Depressors - Paint & Brushes - Palette Paper - Water Containers - Glue - Foam Core - Vinyl Tubing - Spools - Marbles, Ping Pong Balls, Golf Balls - Other - Leggo - Peg Board & Pegs - Dominos - Foss Pulleys

Outline of Instruction

Rube Goldberg in the 21st Century



Students will learn about Rube Goldberg's complicated cartoons and create one of his trademark machines. People have been fascinated by Mr. Goldberg's intricate and often humorous chain reactions for over a century. In many of his machines, Goldberg utilized simple machines, including levers, pulleys, wedges, inclined planes and wheels. Students will be using these illustrations as well as creating Rube Goldberg apparatuses to explore the properties and functions of these ancient machines. In order to share their knowledge and research on simple machines, students will use Makey Makey + Scratch to describe the simple machine and the purpose it served in ancient history.

The Makey Makey is an ingenious tool that simplifies the way we interact with a computer. It is extremely easy to use and its simplicity is what makes it so versatile. The controller works by simply closing a circuit, typically using alligator clips attached to the up, down, left, right, space or click terminal and the "Earth" connector on the Makey Makey. Closing that circuit sends a signal to the computer, telling the computer to press that button. In conjunction with the simple, block based programing language Scratch, students can easily trigger sound effects or graphics/movies on the computer simply by adding a small switch to their project. Some examples of switches are included at the end of the teacher guide

OBJECTIVES

	SKILL / OBJECTIVE	EVIDENCE OF UNDERSTANDING / MASTERY
ENDURING UNDERSTANDING	Simple machines use leverage to help us do big jobs. It can be fun to design complex and interesting machines.	Design and build an original Rube Goldberg invention that uses simple machines.
	I can use innovation and creativity to improvise a complex system using simple machines.	Find and adapt a variety of materials for a new purpose - e.g. half a paper towel roll becomes a chute for a marble.
IMPORTANT TO KNOW AND DO	Simple machines include: levers, pulleys, wheel/ axle, inclined planes, screws, and wedges. Each can be used in several different ways.	Identify and explain the use of simple machines in a picture of an RGM.
	An object can be said to have "potential energy" due to its position in a force-field. An RGM relies on the triggering of a series of objects that have potential energy.	Trace the cause and effect of various components in a drawing of an RGM.
	Gravity exerts a constant force and is a good source of potential energy.	Independently select and use a falling or rolling object in an RGM.
	Electricity requires a complete circut in order to flow.	Correctly design and implement a portion of the RGM that will trigger a reaction from the Makey Makey.
	Some materials conduct electricity while others insulate or resist.	Make discerning selections of materials to use in a Makey Makey circuit.
	Using specific instructions, I can program a computer to sense a change and execute a pre-determined response.	Independently design, code, and implement a program in Scratch that senses input through a Makey Makey and executes a corresponding action.

21ST CENTURY SKILLS	Design Thinking	Show some evidence of prototyping and revision in their process.
	Creativity	Demonstrate a non-typical use for a material or a completely original implementation of some aspect of the machine.
	Collaboration	Coach other students rather than doing the work directly; effectively work through a disagreement; demonstrate effective division of responsibility.
	Perseverance	Display a positive attitude in the face of a major setback. Demonstrate evidence of continued effort despite meager progress.

DAY 1 – PROJECT LAUNCH, CHALLENGE #1 & 2

PROJECT LAUNCH (10 MINUTES):

The project launch is done in the form of a 10 minute mini-lesson. It is intended to create engagement / excitement among students for what they will build. I like to begin with an essential question such as: "**How can we make a simple task into something artistic and fun by making it as complicated as possible**?" I suggest beginning with the OK Go music video linked below as an attention grabber. You should then introduce the concept of a Rube Goldberg Machine and give some basic biographical information about Rube Goldberg. Explain to students that they will be using what they already know about simple machines to design their own Rube Goldberg invention.

Ok Go Video
This incredibly complex RGM will blow students' minds. It's a great way to get the project started.

Rube Goldberg Bio Information
These two links will provide information you need to explain who Rube Goldberg was. You should probably limit what you share with students to only the basics: He was a cartoonist in the early 20th Century that liked to ridicule people's facination with technology by designing machines that were absurdly complex methods of performing simple tasks.

Rube Goldberg Examples
Use these two illustrations of RGMs to help students think about the design of the machines.

CHALLENGE 1 -- IDENTIFY SIMPLE MACHINES

Have students watch the OK Go video again. This time prepare them to watch for examples of simple machines. Review the types of simple machines and point out one or two that you found. Ask them to list the machine they observe when they find it. At the end of the video, have students share what they found. Vocabulary: Potential Energy -- Explain to students that Potential Energy is the potential that an object has to do some work. Water at the top of a mountain has potential energy to turn a mill wheel, generate electricity or uproot a tree. Identify places in the video where objects are positioned in a way that gives them potential energy.

Since this project should be started at the end of the simple machines unit, the class should already be well versed on simple machines and they should be fresh in their minds, but do a wrap up summarization with the class as a refresher. To do this, use a Rube Goldberg illustration and have a class discussion about what simple machines they see in the drawing.

For example:

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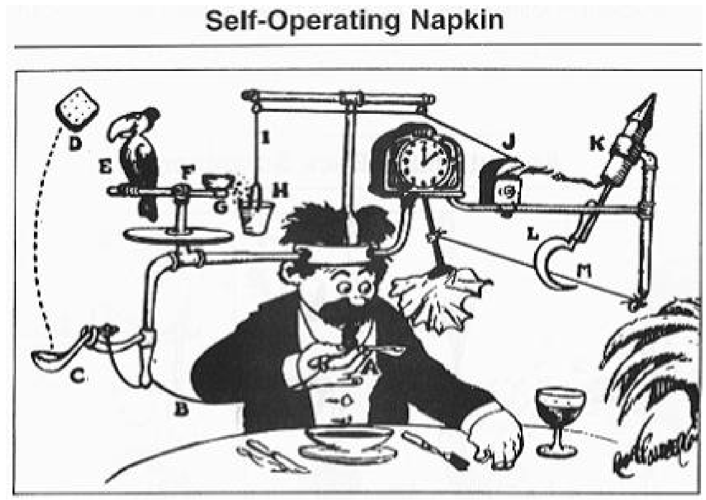


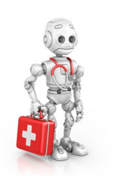
In this self operating napkin I can identify a few simple machines: C- Lever, or fulcrum, H.I.J - A series of pulleys, L,M - wedge (a knife)

CHALLENGE #2 – DRAW AN RGM TO PERFORM A SIMPLE TASK

Have students design their own Rube Goldberg cartoon to solve a simple task, such as popping a balloon or extinguishing a candle. You can either decide to all have one action to work with, or leave the decision up to the students. I do find that having a single focus for the entire class is entertaining, because when you share them all at the end of the class, it is interesting to see how many different solutions can be invented to perform the same task..

- Students must use every type of simple machine in their cartoon and must label all the parts.
- Share them all at the end of the lesson

CHECK FOR UNDERSTANDING



As you circulate, observe students who are having difficulty coming up with an idea. Encourage struggling students to begin at the end and work their way backwards. Remind them about the concept of potential energy and the role that gravity can play. Use targeted questions to start their thinking about the particular properties of some of their materials -- Marbles and golf balls can roll. Tubes and chutes can guide things. Strings can hold things in place. Springs can hold energy. Record examples of growing understanding of objectives and 21st Century skills. Make note of any students who are having significant difficulty for follow-up later.

DAY 2 – MINI-LESSON, CHECK FOR UNDERSTANDING, CHALLENGE #2

MINI-LESSON (LESS THAN 10 MIN)

Begin with the question: “Using Simple Machines, can we have interactions between the physical and digital worlds?” Then show the Makey Makey Introduction Video. Most students will be able to dive right in and build things with the Makey Makey, but some will struggle with the concepts of “circuit” and what is conductive versus what is resistive. Before turning them loose to build, briefly explain the following key points:

- Electricity follows the path of least resistance from an area of high energy to one of low energy. We call that point of low energy “ground.” Makey Makey calls it “Earth.”

- Some material conducts electricity very easily. Other material resists electrical current.
- When you are working with Makey Makey, you are building switches that will open and close the circuits connecting the keyboard commands to Earth on the Makey Makey board.

Makey Makey Intro Video
This video does a better job of explaining how Makey Makey works than any lesson I can think of.

CHECK FOR UNDERSTANDING

After the mini-lesson it is critical to check for understanding among the entire group. I suggest using a polling software such as Socratic to give students a few multiple choice scenarios to check their understanding of the concept of circuit, conductive, resistive, and earth. You can also ask students to do a "fist-to-five" self assessment of what they know. You will have to observe them working on their projects to accurately assess whether they truly understand these concepts and haven't simply memorized the definitions that you gave them in the lesson.

CHALLENGE #3

With a variety of conductive and non-conductive Making materials ready, distribute the Scratch + Makey Makey Handout and ask students to follow the instructions.

Scratch + Makey Makey Handout
This worksheet is freely available from the Makey Makey site. It will help introduce students to writing Scratch programs to work with Makey Makey.

Place students into groups, or allow them to choose their own groups. Groups of 2 - 4 are probably best. Students are now given their task : How can we create a RGM (Rube Goldberg Machine) to take a physical interaction into a digital one? This is where you introduce the Makey Makey. Now, the Makey Makey is basically an RGM in itself: It takes a simple task (pressing a keyboard key) and allows you to make it wayyyy more complicated.

The way it works is you plug it into your USB port on your PC or Mac and it basically pretends it is a keyboard for your computer. The MM will simulate a keypress, and the way that happens is you have to close the circuit from the labeled key on the MM to the ground labeled on the MM, and you can use anything conductive to do that, a simple piece of foil (boring) to an eight person human chain (getting warmer) to tubs of water (both messy AND awesome). All that to simply press the "space" key.

Show the Makey Makey intro video, then hand out the printout I shared above. Students can get started working with the MM. It's best to let them just go at it and try using it and learning it on their own. Have lots of conductive and nonconductive materials around -- skewers, tinfoil, playdough, bananas, copper tape, pencils, pens, etc. etc. -- the more, the better. Allow students to play with some of these simple games / interactive websites.

- http://makeymakey.com/piano/
- http://makeymakey.com/bongos/
- http://ericrosenbaum.github.io/MK-1/

Next, have students create Scratch accounts mit.scratch.edu. Since this is the first year, they may not be familiar with GUI programming, but in following years, the students should be more familiar with block based programming from previous years. Block programming is fairly simple and straightforward, but I would recommend playing around in Scratch yourself in order to get a feel for the interface and how it works. The simple scratch program/tutorial on the handout should be enough for them to get their feet wet and produce the desired result.

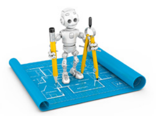
Students can now begin planning out their RGM in earnest.

DAY 3-7 – DEFINE GOALS AND BEGIN PROJECT BUILD

DEFINE GOALS

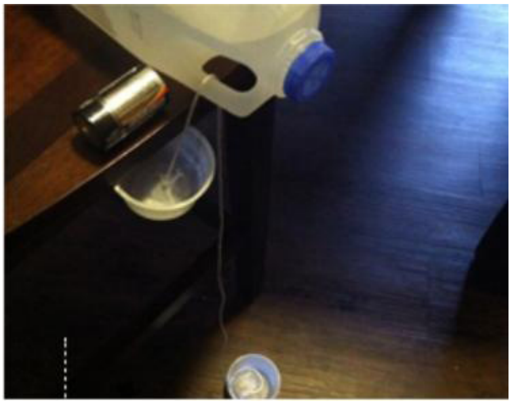
- Discuss as a class what will make a good Rube Goldberg machine.
- Create a rubric (or RUBE-RIC, get it?) with the class tackling what makes a successful contraption.
- How many different steps should it have? How many simple machines? How many physical / digital interactions, and what should they do?
- Ask students to discuss how they might use a simple machine to trigger the makey makey.
- In groups, discuss and design a feasible Rube Goldberg machine using 2 - 3 simple machines.

PROTOTYPE AND REVISE -- BUILD THE MACHINE



Rube Goldberg Machines (RGM) come in all shapes and sizes. Every contraption is different, no two RGM will be the same. Therefore, it is super hard to give specific instructions on how to create one, or have your students make one. But here are some simple tips.

- For cardboard tubing, you can get more out of it if you slice it in half lengthwise. This gives you two channels to run down, and also allows you to see what's going on in the tube.
- Cutting the top off of a soda bottle makes a great funnel, useful for placing rolling marbles into a specific spot.
- Have a balloon pop to lower the weight on a lever or pulley (also demonstrates that air has weight / mass!)
- Fail Fast!
  - While prototyping each component of the machine, try to build the initial design fast to see if it's going to work, if it doesn't, try another design quickly rather than spending more time getting the original design to work.
  - Many of the original designs will fail. Keep trying different ideas out!
  - It may take 2 to 3 designs to find one that will work.
  - If it does work, test it a few times to be sure it is repeatable. If it isn't very reliable, switch it up.
- FOSS Pulleys are great, but it's even better when students can demonstrate their understanding of simple machines by creating their own, like this one using a half gallon of milk:



- Controlling the speed of things can be tough, like a rolling car, or golf ball. Changing the design of your ramps will help. Make a shallow ramp, or a longer ramp. Play with the length of string to speed up, or slow down your moving parts.
- Pegboard makes for a great prototyping surface. It can be stood up or leaned back to produce different effects and it can be modified rapidly.
- You can also add a chemical reaction, by having baking soda + vinegar activate one of your steps, OR to trigger the makey makey!
- When you start to build your final design, keep steps to a minimum at first and try and perfect each step before moving onto the next one. Building too much at a time can get messy and confusing.
- Levers are some of the most versatile ways to link steps. Don't underestimate them!
- And last, but certainly not least! -- The simplest method is often the best method!

SHOW WHAT YOU KNOW -- MAKE A VIDEO OF A WORKING MACHINE

Have students work on building their machines, documenting the process of the build using iPads, or any device that can shoot photos and video.

Have the students narrate what will be happening before pressing “play” on the machine.

REQUIREMENTS / CONSTRAINTS:

Below are a list of possible guidelines. Feel free to tweak them based on class dynamic / time allowance.

- Number of steps required: Students may need different numbers of steps to complete their task.
- Triggers: How many Makey Makey triggers are required? Triggers can either be sprinkled throughout or placed at the end of the contraption. They can either play a sound, or trigger an animation on the computer.
- Video: Thoughtful setup of shots. Good use of close-up and wide angles. Audio is clear and at an appropriate volume.

IDEAS FOR ENHANCEMENTS & EXTRAS:

Use the Light Blue Bean to interact with the machine instead of a Makey Makey. This can use physical inputs and outputs in the form of a servo motor, allowing an input to trigger a motor and send another part of the RGM into motion.

SUGGESTIONS FOR ACCOMMODATIONS OR DIFFERENTIATION:

Teachers can use any of the suggestions below to tailor the project to meet scheduling needs of their class, ability levels of their students, or content knowledge of their students.

- Use pre-made pulleys and levers from FOSS kits to ease some of the building steps.
- Lego / Duplo are HIGHLY recommended. Kids already know how to use them and they’re great for making structures.
- Encourage lots of testing. And remember: part of the learning process is failing!
- The video recording / production can be cut based on time constraints.
- The number of simple machines required can be increased or decreased to make the projects more or less challenging.
- All of the projects can be combined into a single-class, giant RGM project!
- If necessary, the Makey Makey part can be cut out, but I find that extra challenge and digital / physical interaction is an interesting requirement for the students to learn. Plus, I think Rube Goldberg would totally approve.

NOTES FOR INSTRUCTORS:

THESE MACHINES WILL FAIL. They will fail a lot. They will fail spectacularly. That’s where the learning happens! Allow students to make a mess and experiment with their chain reactions.

They will take up space in the classroom. It may be tough to store them away, so it may be best to take the building phase as one long class.

Genesis Learning