AMERICAN PRECISION MUSEUM

START HERE!

Welcome to Achieving Repeatability!

SPARK SHOP

WARM-UP

Take everything out of your box. What do you think you'll create with these materials?

REFLECT

Describe a time where you had to make a big number of identical things. Maybe it was a craft, food, gift, or invention. What was the object and how did you make it?




WHAT YOU'LL LEARN

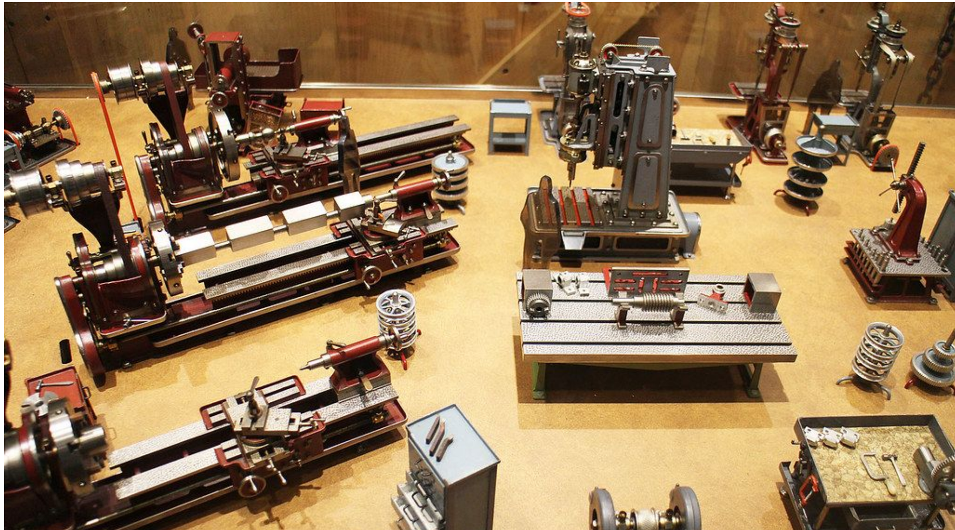
Most of the things around us are **mass-produced**, meaning they are made in factories that manufacture thousands or even millions of them, usually using machines! Engineers work hard to make sure that when parts are mass-produced, they are all **identical** to one another. You wouldn't want your two shoes to be different sizes, would you?

In these activities, you'll explore how people learned to make **repeatable** parts, as well as how you can achieve repeatability in your own life!

WHO MADE THIS?

This kit is from the **American Precision Museum** in Windsor, Vermont. The museum holds America's largest collection of historic machine tools! They are committed to preserving and sharing our country's history of **innovation** and **manufacturing**. You can visit the museum to explore their hands-on exhibits in person!

To design the activities you are about to do, the American Precision Museum collaborated with **SparkShop**, an engineering education nonprofit in Chicago, Illinois.



Answer a few questions at the link below to get started!

https://forms.gle/xWQ5Xyca8VzcGH6m7

HISTORY

REPEATABILITY IN SHOEMAKING

WARM-UP

What do these tools have in common?

WARM-UP

All of these tools are used to create **identical** shapes every time they are used!

WHAT IS REPEATABILITY?

When a process is **repeatable**, it means it creates the same results every time.

Repeatability is an especially important requirement for **engineers** and **manufacturers**!

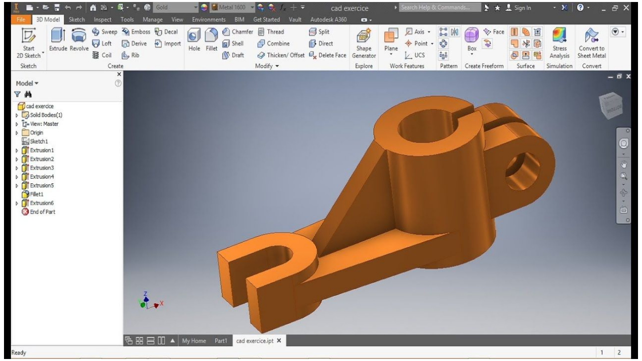
You'll learn how past inventors built tools to achieve repeatability!

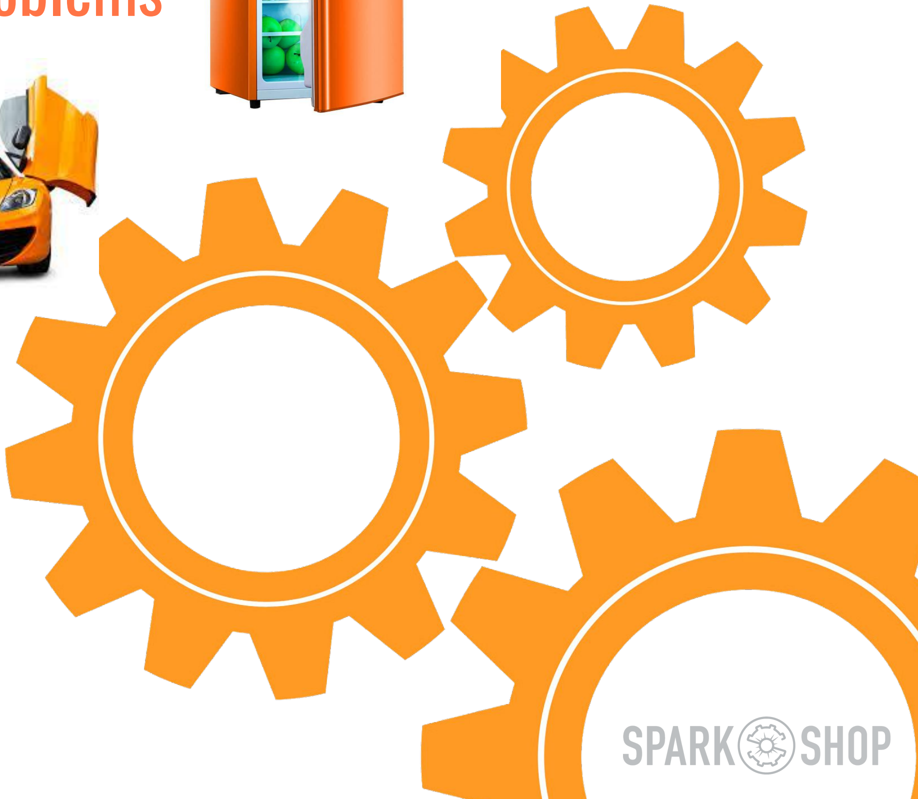
ENGINEERS

Design and **invent** things to solve problems





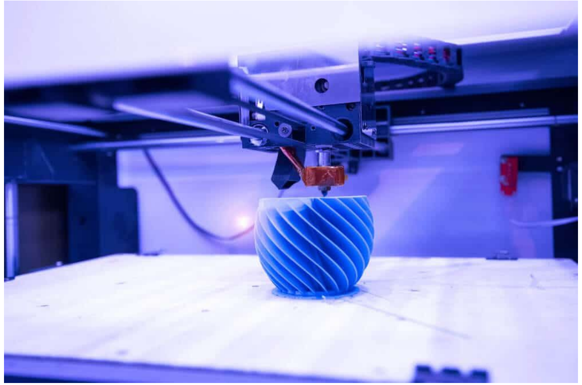



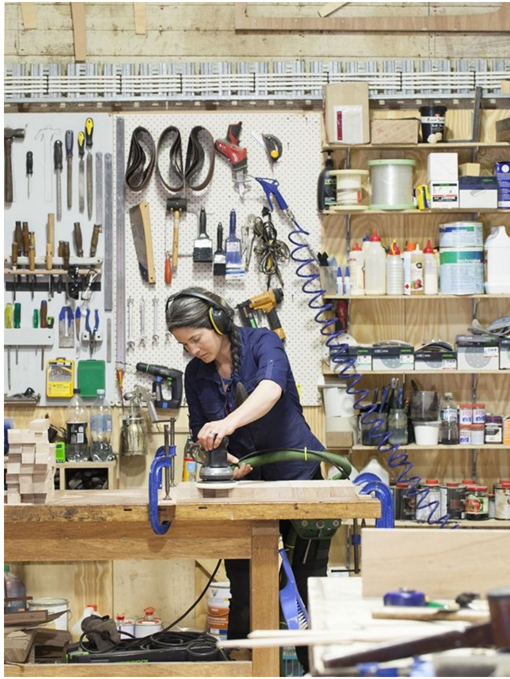


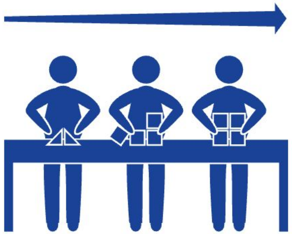
SPARK SHOP

MANUFACTURERS

Use tools and **technology** to make things







HYPOTHESIZE

Why is repeatability important for people who design and build things?

How could manufacturers make processes repeatable?

ACTIVITY

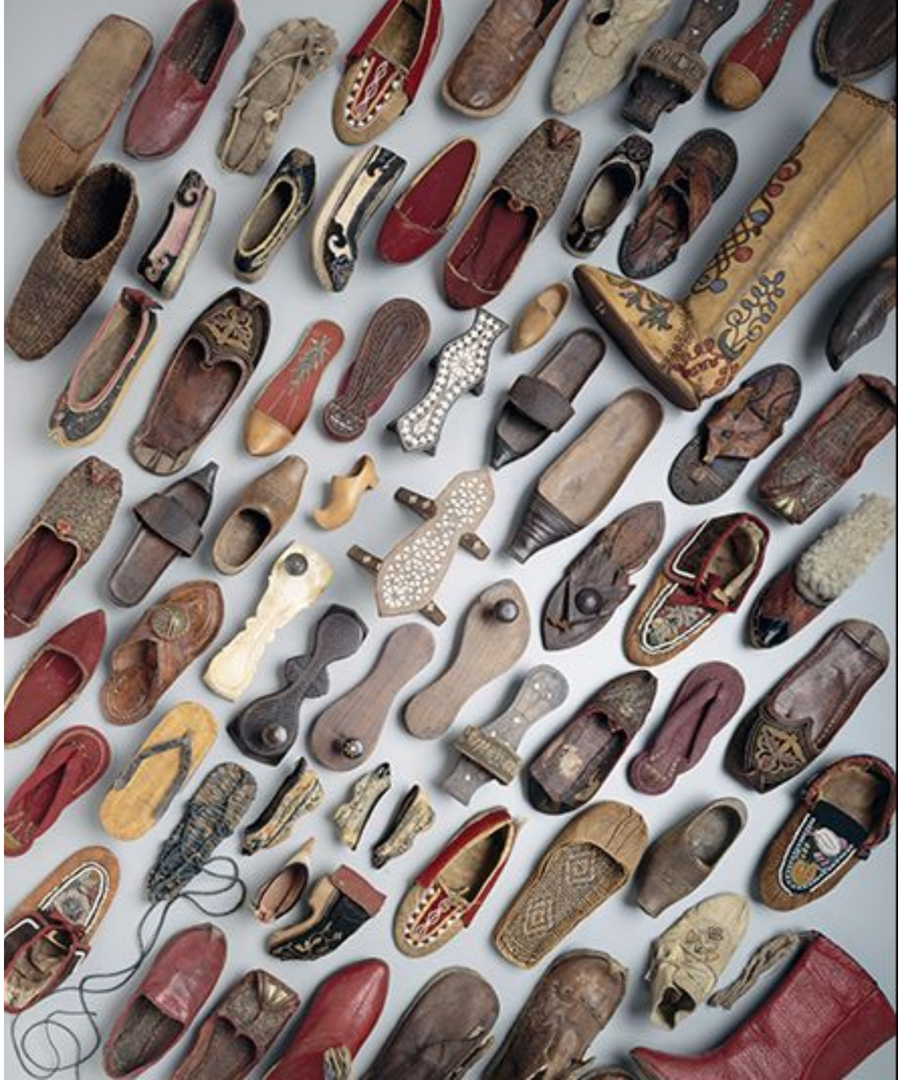
Explore the history of shoe manufacturing

HISTORY OF SHOEMAKING

People have been **creating** things since our earliest days. Throughout time, we have used tools to make our processes easier, faster, and more repeatable.

Let's look at how tools (and later, machines) were used by **shoe manufacturers** to make processes repeatable.

An example of an early American shoe-building tool is on display at the American Precision Museum.



THE FIRST SHOES

The earliest shoes that historians have discovered were made in **8000 BCE**. Those sandals, made out of bark, were found in what is now Oregon. The first leather shoes date back to **3500 BCE** and were discovered in what is now Armenia. Historians believe shoes were worn even earlier, but because they were made out of **biodegradable** materials, most of them haven't survived.

These shoes were made by hand with simple tools. Each shoe would have looked different from the one made before it because each piece of material was cut with a knife and **woven** by hand. *Does that sound repeatable to you?*

SPARK SHOP

INFER

Using context clues from the passage, what does the word **biodegradable** mean?

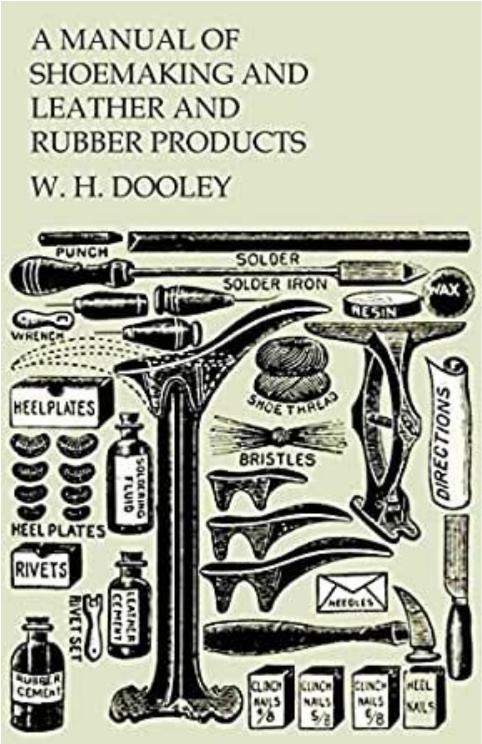
"Historians believe shoes were worn even earlier, but because they were made out of ***biodegradable*** *materials, most of them haven't survived."*

Write your answer here:

HAND TOOLS

Over time, shoemakers developed specific **tools** to help them form the complex shapes required in shoes. To make the best shoes, **cobblers** would custom design the shoe to perfectly fit their customer's foot, but this process took lots of time and money. Nice, custom-made shoes were not **affordable** for most people. To save money, cheaper shoes were poorly shaped and usually not directional (meaning there weren't different designs for right and left feet!).

Then, **inventors** designed tools that allowed cobblers to craft and stitch leather into standard shapes, making their processes **repeatable**!



This book was originally published in 1912 and shows a sampling of the tools a cobbler at the time might have used.

Mini Activity

1. Get at least 2 pieces of paper.
2. Try to fold one page into the shape of your foot.
3. Use the second page to try again using a different technique.
4. *Optional: repeat with extra paper*

Share out!

Discuss the questions on the right:

- What techniques did you try?
- How did it turn out?
- What worked best?
- What was hard?

INDUSTRIAL REVOLUTION

In the late 1800s, shoe-making technology took off! Innovation in the **Industrial Revolution** brought about the sewing machine, which made the process faster and more precise. **Entrepreneurs** built factories and purchased machines so they could produce shoes faster and more easily than a craftsperson.

New England was home to some of America's best shoe-making factories. The **Ascutney Shoe Factory**, pictured here, was just 5 miles south of where the American Precision Museum is today!

Ascutney Shoe Factory
Courtesy of the Windsor Historical Society

EXAMPLE: SHOE LAST

The **shoe last** was a mold invented for shoemaking. It was made out of wood and carved into the shape of a foot. It had two uses:

1. **Measuring** the material needed for a shoe by draping leather over the last
2. **Holding** different pieces of leather in place while they are stitched together

When manufacturers used lasts, their process became repeatable! Shoes could be produced in standard shapes and sizes. This made it possible for people to know that a shoe would fit their foot based on its size.

The **American Precision Museum** in Windsor, VT has preserved shoe lasts and leather shoes made in New England during the Industrial Revolution.

Ascutney Shoe Factory
Courtesy of the Windsor Historical Society

EXAMPLE: BLANCHARD LATHE

The first machine tool that made shoe lasts was the **Blanchard lathe**. Lathes shape things by spinning a raw material and **carving** it with sharp cutting tools. The process is similar to what happens when you twist a pencil in a pencil sharpener!

The Blanchard lathe uses a metal copy of the final shape as a guide. As the machine traces the object, it moves the cutting tool to carve an **identical** shape from a piece of wood. The metal guide can be reused to create countless **repeatable copies** of the shape!

This meant different shoemakers across the country could use identical shoe lasts, making shoe sizing **standard** and **predictable**!

MODERN TECHNOLOGY

Watch the video below and look for examples of tools and machines that help Vans achieve repeatability today.

SCAN ME

WHAT IF SHOEMAKING WASN'T REPEATABLE?

Without repeatability, a manufacturing process produces **unpredictable** results. If shoemakers didn't use tools and machinery to make their shoes, you could expect:

- Irregular sizes
- Shoes that don't match
- Quality errors (like missing stitches)
- Wrong colors
- And more

Modern technology has made those problems rare! Almost all of the **products** around you were made using predictable, repeatable processes.

SUMMARIZE

In your own words, describe how shoe manufacturing has changed over time:

REFLECTION

What is a tool you use that helps you achieve repeatability?

How would life be different if manufacturers couldn't make processes repeatable?

BONUS VIDEO

Watch to see how engineers use modern machines to test and improve shoes.

SCAN ME

STEM CHALLENGE

PEN DECONSTRUCTION

WARM-UP

Carefully take apart the red and white pen in your Repeatability Material Kit.

WARM-UP

Carefully take apart the red and white pen in your Achieving Repeatability Kit.

ANALYZE

How many pieces did you separate?

Name all the materials you recognize in the parts of your pen:

WARM-UP (Part 2)

Put your pen back together!

ANALYZE

How hard was it to reassemble your pen? Drag the orange circle over your answer:

1	2	3	4	5
Easy				Hard

Explain why you chose your answer:

SPARK SHOP

ANALYZE

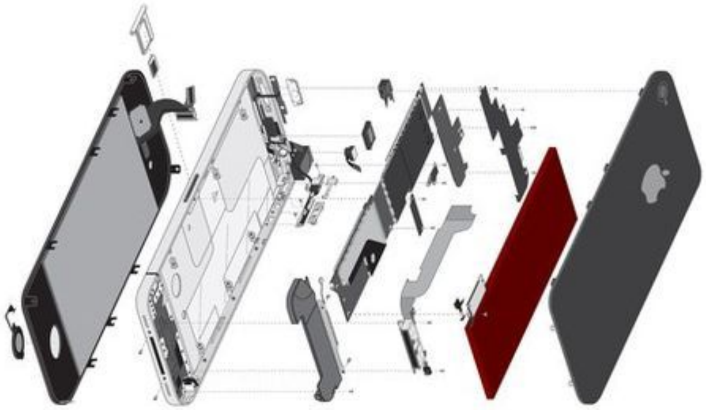
How hard was it to reassemble your pen?

1	2	3	4	5
Easy				Hard

Explain why you chose your answer:

ASSEMBLIES AND PARTS

Your pen is an example of an **assembly.** An assembly is a product made of multiple smaller **parts** attached together. Complex assemblies like computers or cars can have hundreds (or even thousands) of individual parts!



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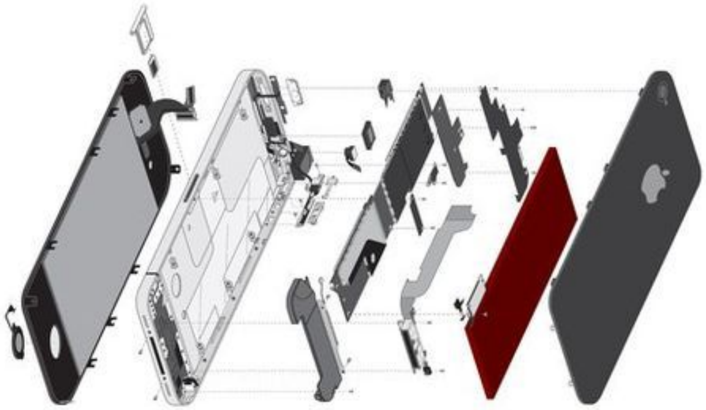


ACTIVITY

Experiment with interchangeable parts!

PROCEDURE

1. Get your blue and orange SparkShop pen from your material kit.
2. Disassemble both of your pens.
3. Shuffle the parts around on your desk or table.

Can you tell which spring came from which pen?

SPARK SHOP

PROCEDURE

1. Get your blue and orange SparkShop pen from your material kit.
2. Disassemble both of your pens.
3. Shuffle the parts around on your desk or table.

Can you tell which spring came from which pen?

PROCEDURE

4. Reassemble two pens from the parts in front of you so that the pens look the same as they did at the beginning.

Do both pens still work? Why or why not?

PROCEDURE

4. Reassemble two pens from the parts in front of you so that the pens look the same as they did at the beginning.

Do both pens still work? Why or why not?

PROCEDURE

5. Take apart and reassemble your pens so you have different color combinations than you started with.

Do both pens still work? Why or why not?

PROCEDURE

5. Take apart and reassemble your pens so you have different color combinations than you started with.

Do both pens still work? Why or why not?

DRAW CONCLUSIONS

What is different about the two pens?

Why do the pens still work even if they're reassembled with other parts?

INDUSTRY CONNECTION

Lego parts have to be interchangeable so they can always fit together. Watch the video below until 3:15 to see how the engineers at Lego make this possible!

SPARK SHOP

REFLECTION

Name one product you use that is an assembly with more than 100 parts:

Why do engineers design assemblies made out of interchangeable parts?

STEM CHALLENGE

TESSELLATION COOKIE CUTTERS

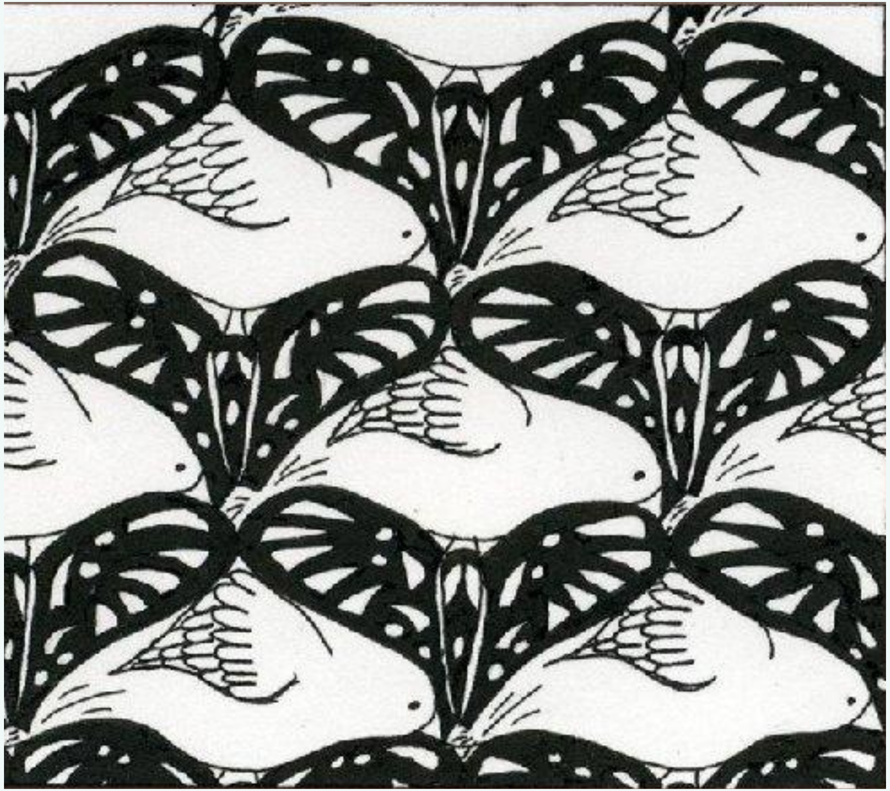
SPARK SHOP

WARM UP

TESSELLATION ILLUSIONS

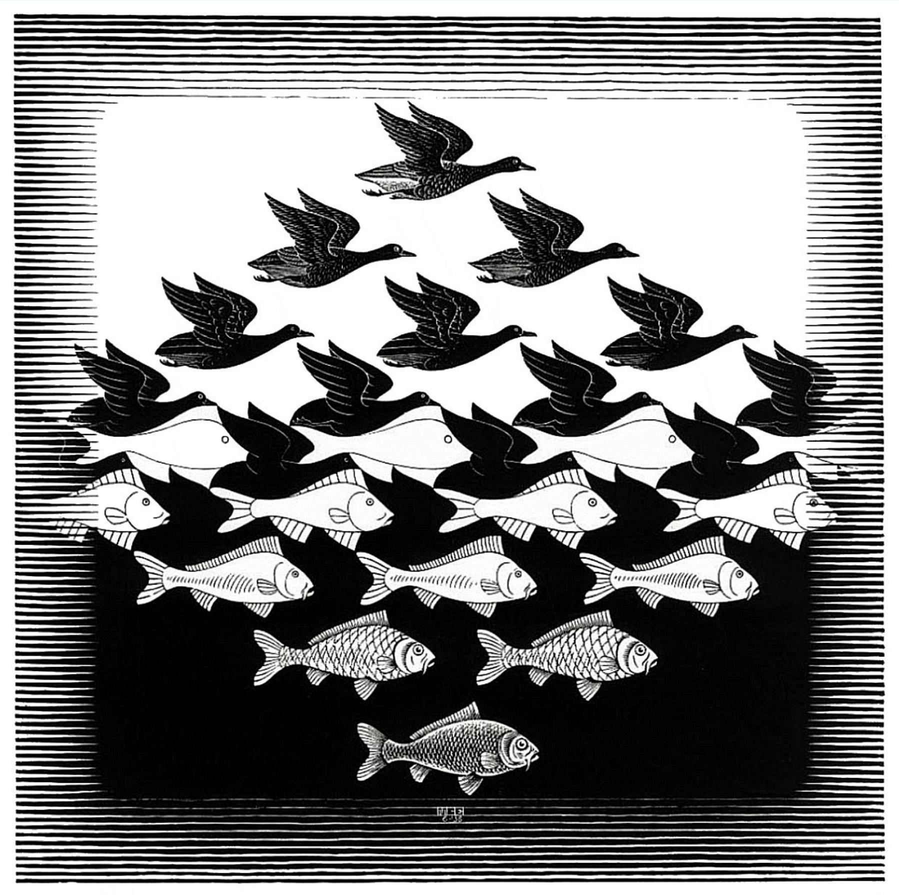
WARM-UP

- There are two creatures in this image.
- What are they?



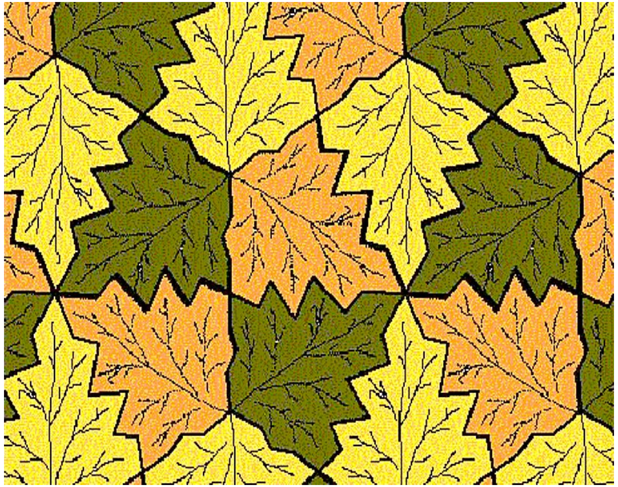
WARM-UP

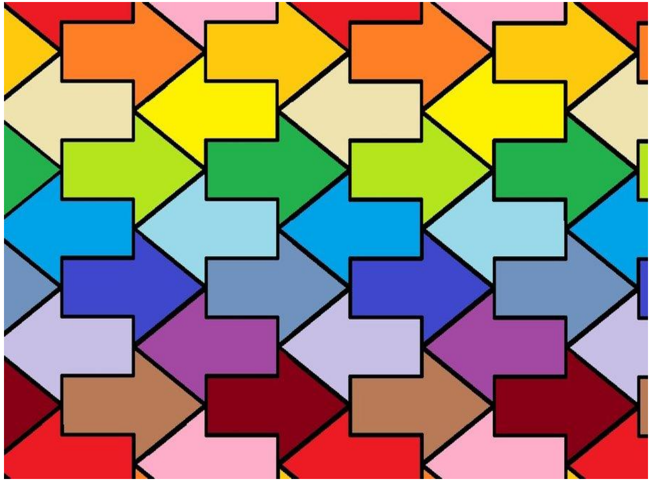
- There are two creatures in this image.
- What are they?



WHAT IS A TESSELLATION?

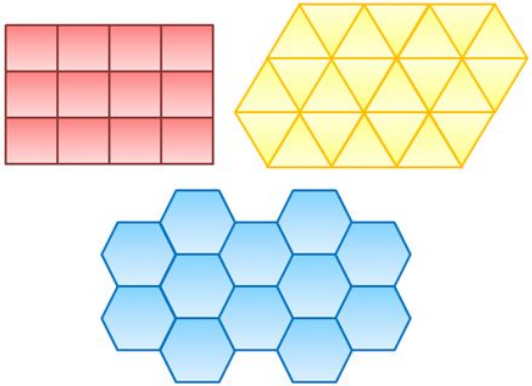
- Look at these examples below. All of these are **tessellations!**
- What do you think is a tessellation based on these examples?

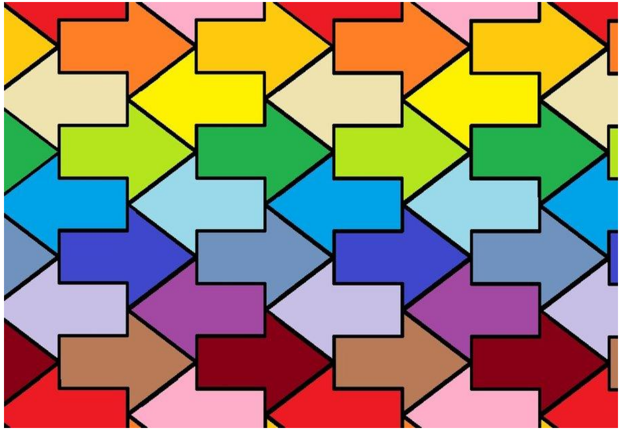




TESSELLATIONS

Tessellations are **repeating shapes** with no gaps or **overlaps**





The outlines or shapes nest into each other so it creates a **repeated pattern**!

ACTIVITY

TESSELLATION COOKIE CUTTER

SPARK SHOP

TESSELLATION COOKIE CUTTERS:

SCAN ME

TESSELLATION COOKIE CUTTER

- You will be making a **tessellation** pattern for cookies!
- The cookies will have a **repeating pattern** with no gaps or wasted space!
- The tool you build will make your cookie cutting process **repeatable**!

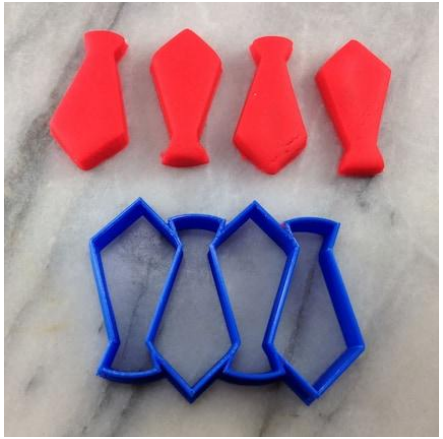
COOKIE CUTTER IDEAS

- Come up with a simple shape! Here are some ideas

PUZZLE PIECE

CHRISTMAS TREE

HEXAGONS

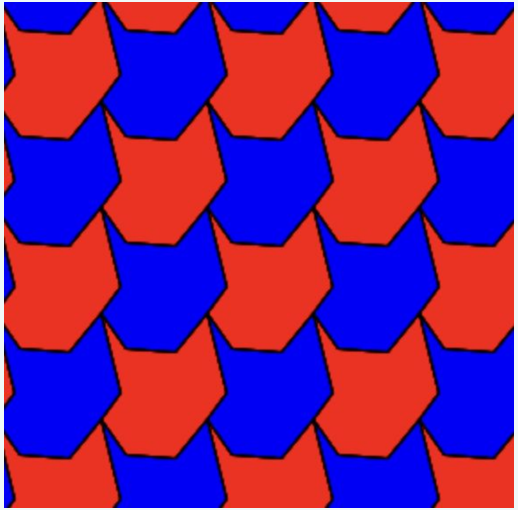


DRESS TIES

SPARK SHOP

PART 1: DESIGN

Experiment with creating tessellations at:
https://bit.ly/generator-tess



Drag parts of the shape to modify it

Click tessellate to tile your shape

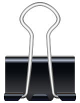
Click reset to start over

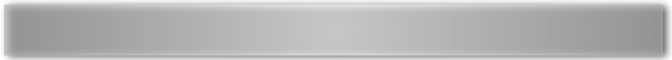
PART 2: PROTOTYPE

- Play-Doh
- Cookie cutter tin
- Binder clip

PROTOTYPING

- Take your **cookie cutter tin** and shape it.
- Be patient, it’s not easy to bend it. Keep trying.
- Be cautious: it’s not that sharp but be mindful.
- Seal it with your **binder clip**





Caution: Sharp Edge

SCAN ME

SPARK SHOP

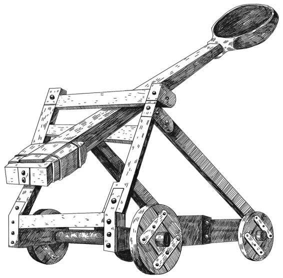
TESTING

SCAN ME

REFLECTION

Reflect: How would you iterate or improve on your cookie cutter if you made another prototype?

INSERT A PHOTO OF
YOUR PROTOTYPE HERE

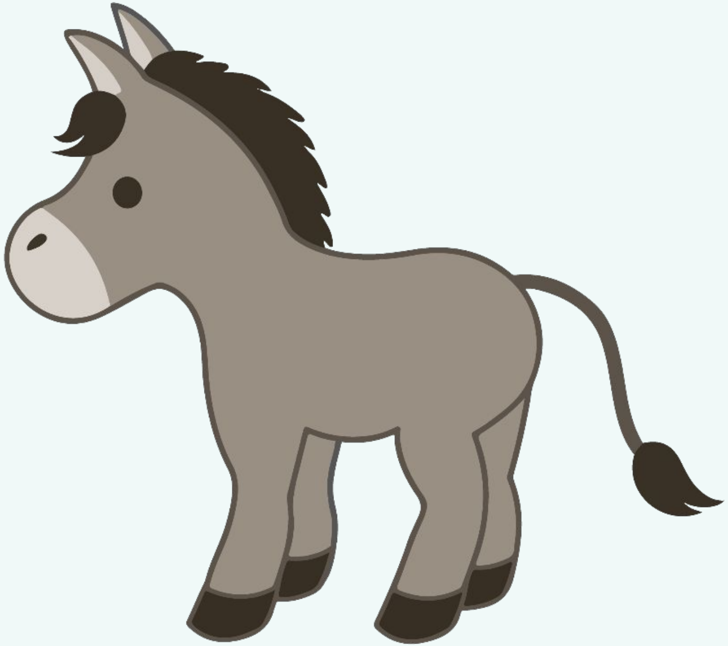


STEM CHALLENGE

REPEATABLE CATAPULT

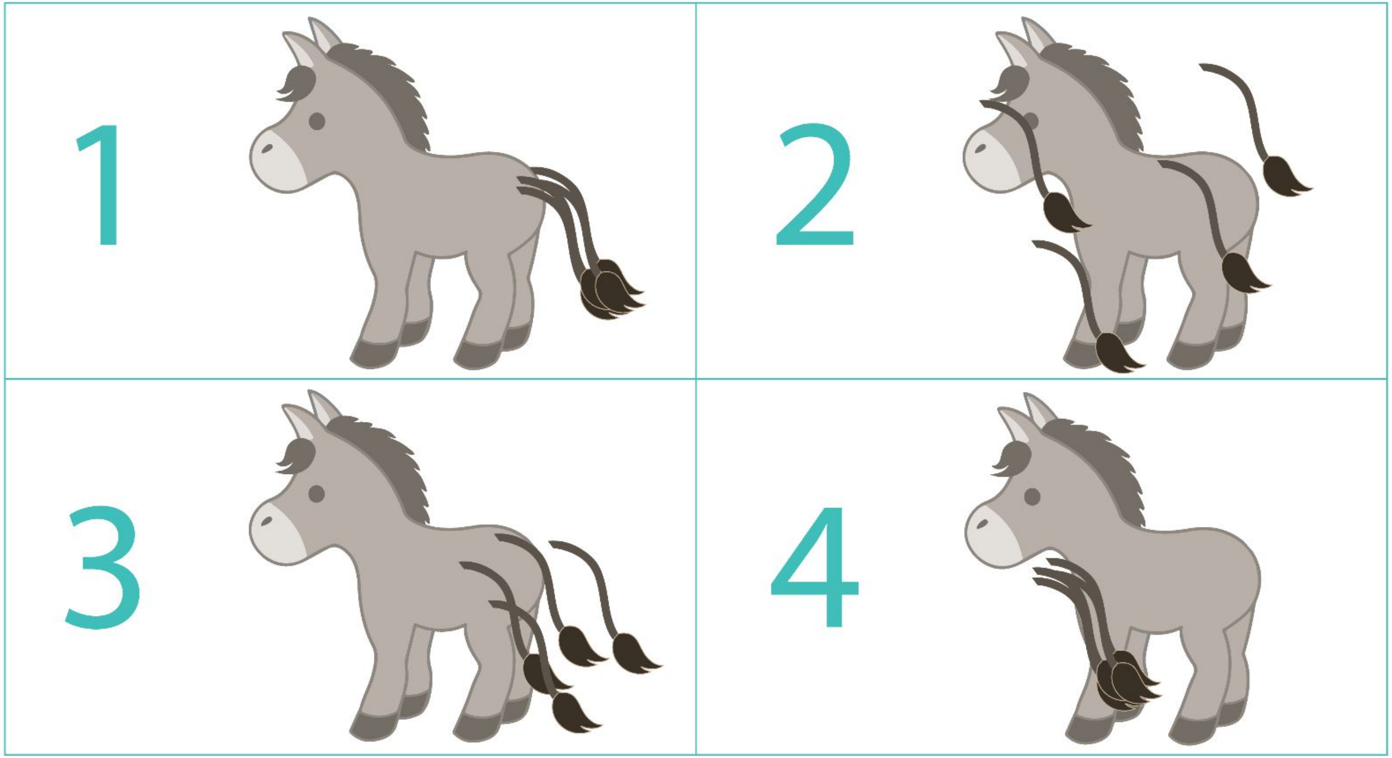
Warm-up

What is the goal of the game "Pin the Tail on the Donkey?"



DISCUSS:

Here are the results of four games. How would you describe their differences?



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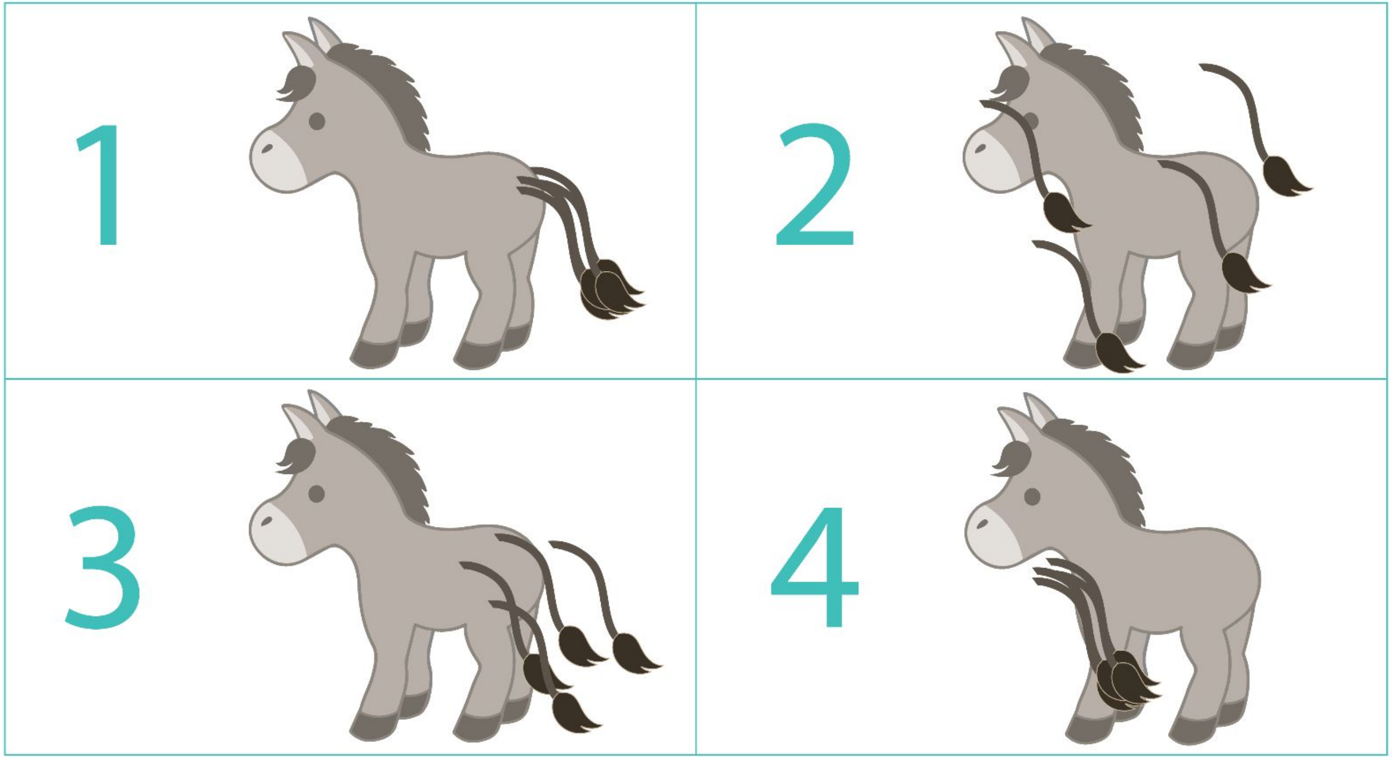
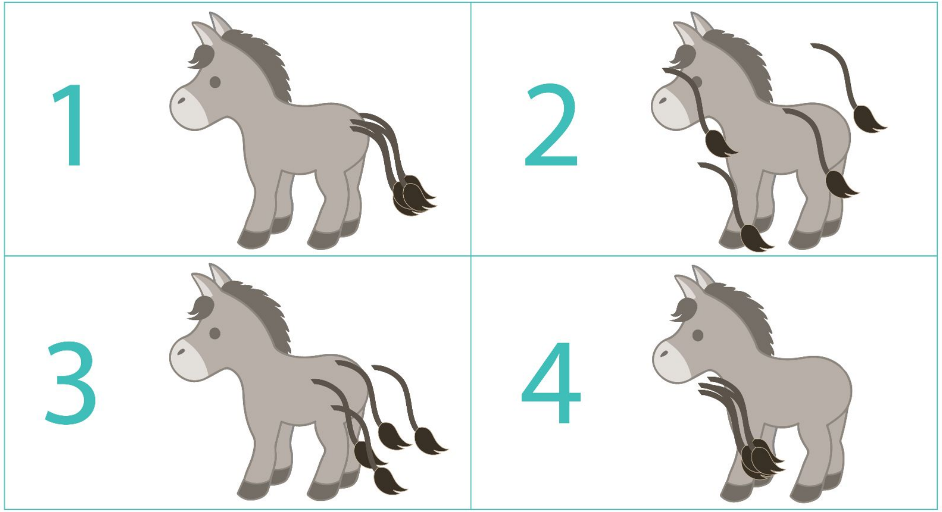


ACCURATE VS. PRECISE

In games 1 and 4, the different tails are placed close to each other. These results are **precise**, because the result is similar everytime.

In games 1 and 3, the results are **accurate**, meaning they are close to the correct answer.

Game 2 is neither accurate nor precise.



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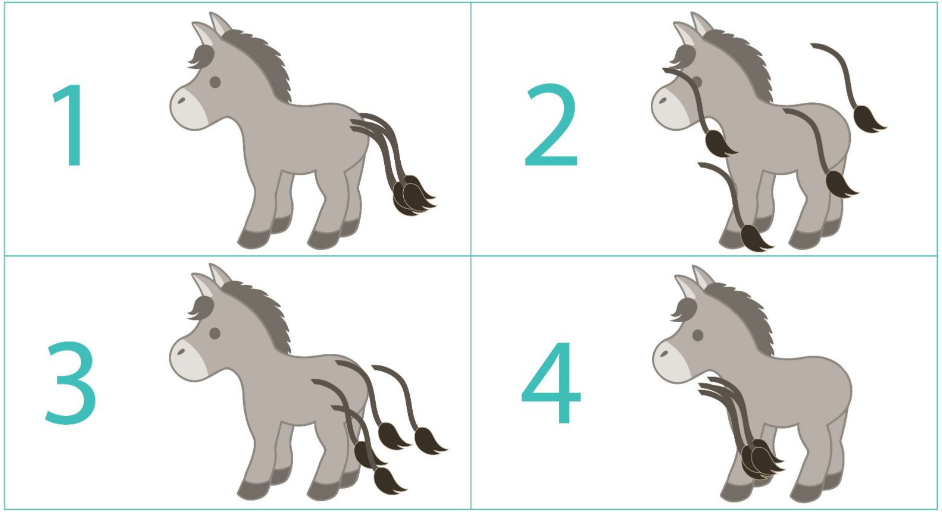


In games 1 and 3, the results are **accurate**, meaning they are close to the correct answer.

Game 2 is neither accurate nor precise.

REPEATABILITY CONNECTION

When a process is **repeatable**, the results are **the same every time.**

Check for understanding: does that mean results are accurate or precise? Why?

REPEATABILITY CONNECTION

When a process is **repeatable**, the results are the same every time.

Check for understanding: does that mean results are accurate or precise? Why?

ACTIVITY

Build & test a mini-catapult!

OBJECTIVES

- Build a catapult
- Run an experiment
- Improve your catapult to improve precision and accuracy
- Rerun the experiment

MATERIALS

- “Achieving Repeatability” Material Kit
- 5 popsicle sticks
- 4 rubber bands
- 1 plastic spoon
- 1 styrofoam ball

OBJECTIVES

- Build a catapult
- Run an experiment
- Improve your catapult to increase precision and accuracy
- Rerun the experiment

MATERIALS

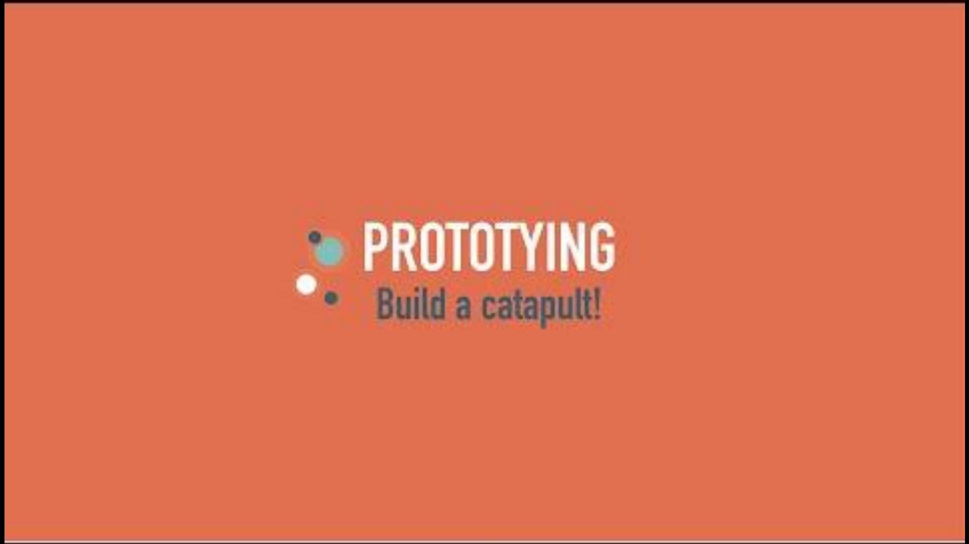
- “Achieving Repeatability” Material Kit
- 5 popsicle sticks
- 4 rubber bands
- 1 plastic spoon
- 1 styrofoam ball

SPARK SHOP

BUILD YOUR CATAPULT

Follow along with the video

SCAN ME



EXPERIMENT PROCEDURE

1. Open your material kit.
2. Place your catapult in front of the kit.
3. Try to shoot the styrofoam ball into the box 10 times.
4. In the table below, type an X if it lands in the box and an O if it misses.

	1	2	3	4	5	6	7	8	9	10
Hit (X) or Miss (O)										

Were your results precise, accurate, neither, or both?

EXPERIMENT PROCEDURE

1. Open your material kit.
2. Place your catapult in front of the kit.
3. Try to shoot the styrofoam ball into the box 10 times.
4. Record an X if it lands in the box and an O if it misses.

	1	2	3	4	5	6	7	8	9	10
Hit (X) or Miss (O)										

Were your results precise, accurate, neither, or both?

IMPROVE

5. Make a modification to your catapult to make your results more precise.You can use materials to change your catapult or change your launch technique. Be creative!

6. Rerun your test and record results below:

	1	2	3	4	5	6	7	8	9	10
Hit (X) or Miss (O)										

Were your results precise, accurate, neither, or both?

IMPROVE

5. Make a **modification** to your catapult to make your results more accurate and precise. You can use materials to change your catapult or change your launch **technique**. Be creative!

6. Rerun your test and record results below:

	1	2	3	4	5	6	7	8	9	10
Hit (X) or Miss (O)										

Were your results precise, accurate, neither, or both?

REFLECT

Describe how you improved your catapult:

Why is it important for a catapult to be precise and accurate?

OPTIONAL BONUS

7. Make a **second** modification to your catapult to make your results more precise and accurate.You can use materials to change your catapult or change your launch technique. Be creative!

6. Rerun your test and record results below:

	1	2	3	4	5	6	7	8	9	10
Hit (X) or Miss (O)										

Were your results precise, accurate, neither, or both?

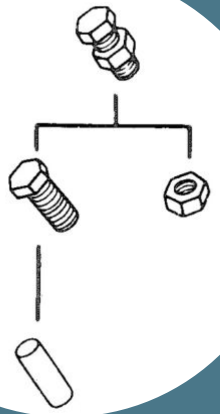
OPTIONAL BONUS

7. Make a second **modification** to your catapult to make your results more accurate and precise. You can use materials to change your catapult or change your launch **technique**. Be creative!

6. Rerun your test and record results below:

	1	2	3	4	5	6	7	8	9	10
Hit (X) or Miss (O)										

Were your results precise, accurate, neither, or both?



WRITING ACTIVITY

BILL OF MATERIALS

BILL OF MATERIALS

Most products are **assemblies**, made up of many individual parts. When engineers design a product, they keep a detailed record of every part in it. This list of every part in an assembly is called a **bill of materials.**

Here is an example of a bill of materials. Based on the parts, can you guess what assembly this is for?

Quantity	Image	Desc
4		Wheel
1		Deck
2		Axle
8		Screw

BILL OF MATERIALS

As an engineer, you can use a bill of materials to hold a variety of information!

Extra columns in the table can describe cost, color, description, source, weight, or any other relevant characteristic. Sketches or pictures of parts make a bill of materials easier to understand.

Part Number	Quantity	Image	Desc	Cost	Color	Size	Material	Manufacturer	Vendor
100	4		Wheel	$2	White	2"	Plastic	ZWheels	Malibu Skate
200	1		Deck	$3	Brown	36"	Wood	Tony Hawk	Malibu Skate
300	2		Axle	$3	N/A	8"	Aluminum	Cal Skate	Malibu Skate
400	8		Screw	$0.3	Black	¼"x1"	Steel	N/A	Grainger

ACTIVITY

Create a Bill of Materials

SPARK SHOP

OBJECTIVES

- Build a bill of materials for 2 different assemblies
- Name each part in the assembly
- *Optional: create small drawings of each part*

MATERIALS

- Pen
- Pencil
- 2 sheets of paper
- 1 assembly that you're allowed to take apart (details on page 7)

1. PEN BILL OF MATERIALS

Warm up by making a bill of materials for something familiar: your pen! You can use either pen from your material kit for this activity.

1. Copy the table on the right on a piece of paper.
2. Give each part of the pen a **descriptive** name.
3. Draw a small sketch of each part.

Part Number	Part Name	Sketch
1		
2		
3		
4		
5		

2. NEW BILL OF MATERIALS

Now, find another assembly and get permission to take it apart. This could be a toy, kitchen **gadget**, broken **appliance**, or something else!

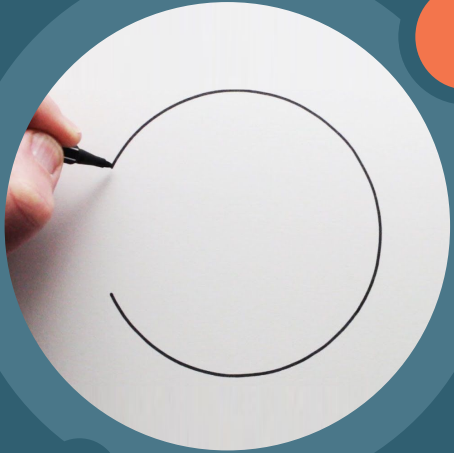
1. Copy the table on the right on a piece of paper. Leave room at the bottom in case you have more than 5 parts.
2. Pick one more piece of **information** to record in the last column, like color, size, or something else.
3. Give each part of the **assembly** a descriptive name.
4. Draw a small sketch of each part.

Part Number	Part Name	Sketch	*(Your choice)*
1			
2			
3			
4			
5			

REFLECT

How does a bill of materials help engineers achieve repeatability?

Do you use anything similar to a bill of materials in your life? *(Consider other types of lists)*



ART ACTIVITY

DRAWING CIRCLES

SPARK SHOP

WARM-UP

Artists use lots of tools! How many can you identify in the picture here:

DRAWING CHALLENGE

Create perfect circles using different tools

OBJECTIVES

- Experiment with different ways to draw a circle
- Identify the strengths and weaknesses of each process
- Compare processes using criteria

MATERIALS

- Pencil
- Pen
- Compass
- Rubber band
- String
- Play-Doh
- 5 pieces of paper

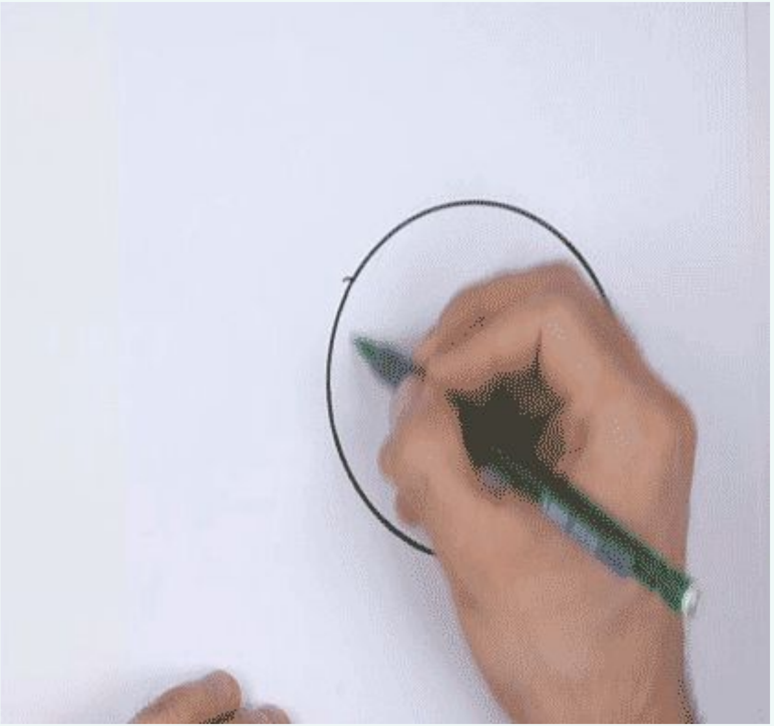
PROCEDURE

On every following slide, you will:

1. Learn a process for drawing circles
2. Practice the process 5 times on one sheet of paper
3. Identify strengths and weaknesses of the process

1. Freehand Drawing

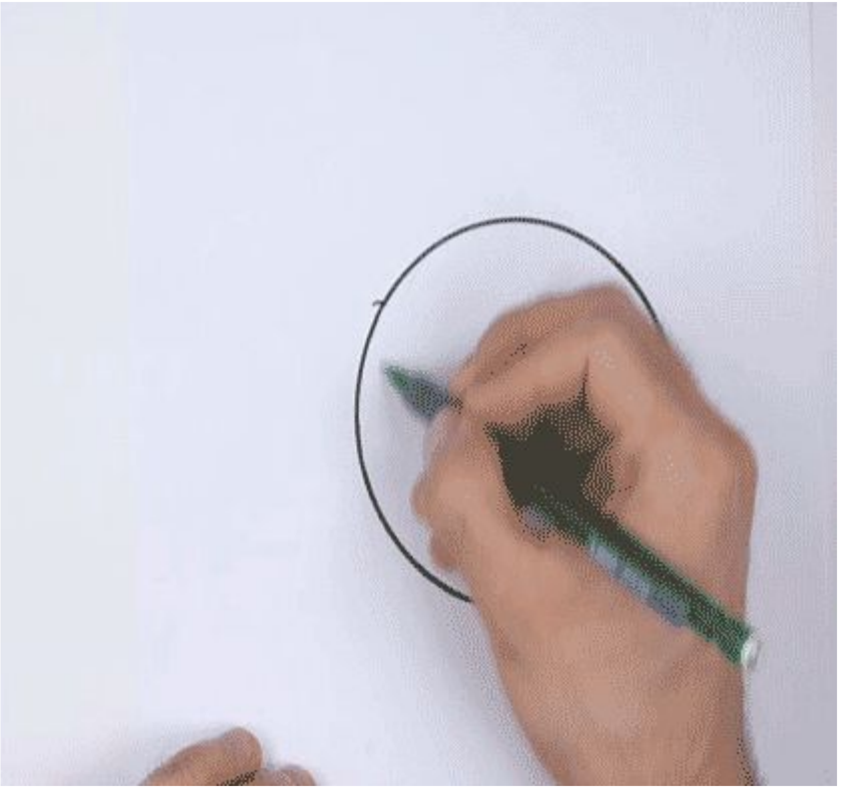
On your first piece of paper, use **only** a pencil to draw 5 circles.



FREEHAND DRAWING

Think about the strengths and weaknesses of freehand drawing. Look at the examples in the table below and **add at least one** more strength and weakness

STRENGTHS	WEAKNESSES
Fast	*Not repeatable*

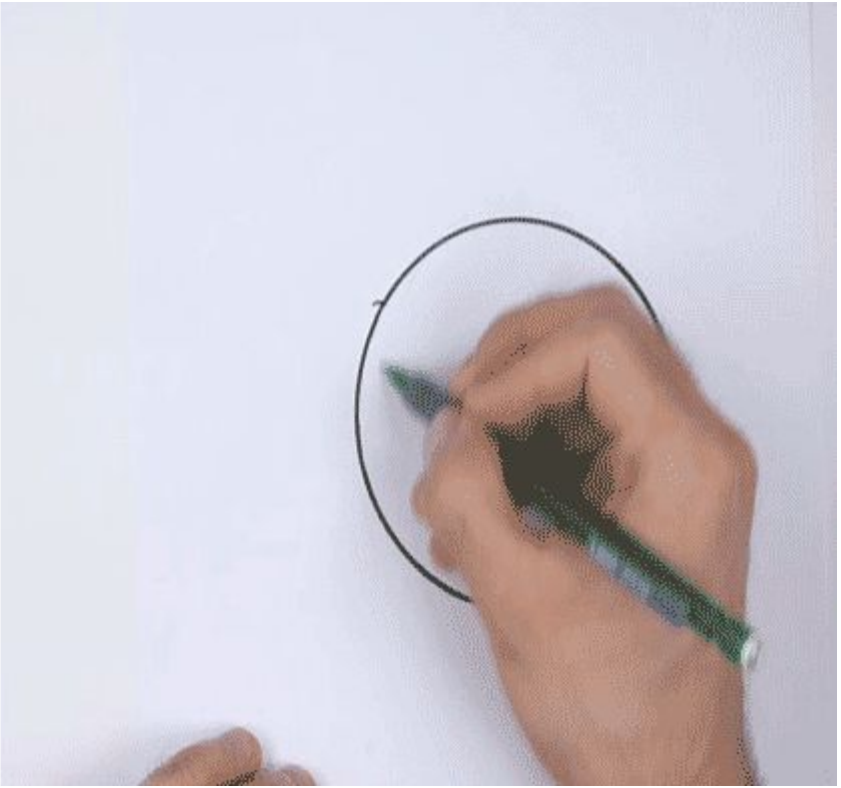


SPARK SHOP

FREEHAND DRAWING

Think about the **strengths** and **weaknesses** of freehand drawing. Look at the examples in the table below and add at least one more strength and weakness.

STRENGTHS	WEAKNESSES
Fast	*Not repeatable*



2. Compass

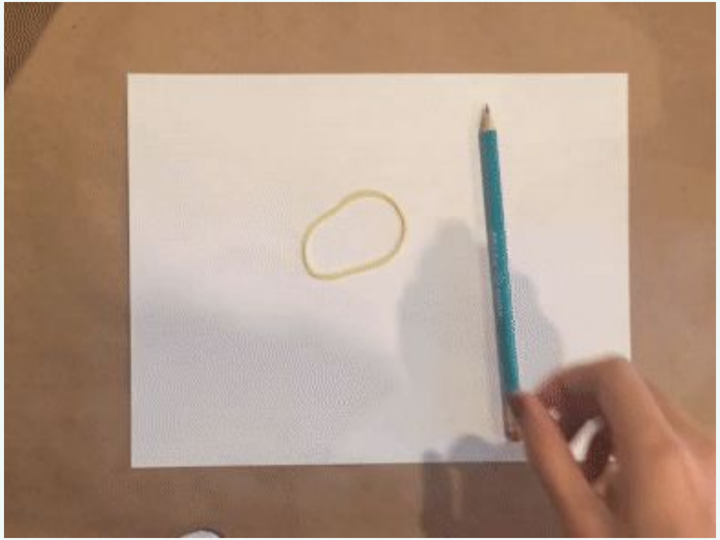
On a second piece of paper, use a **compass** to draw 5 circles.

COMPASS

Think about the strengths and weaknesses of the compass method. Write at least two answers for each:

STRENGTHS	WEAKNESSES

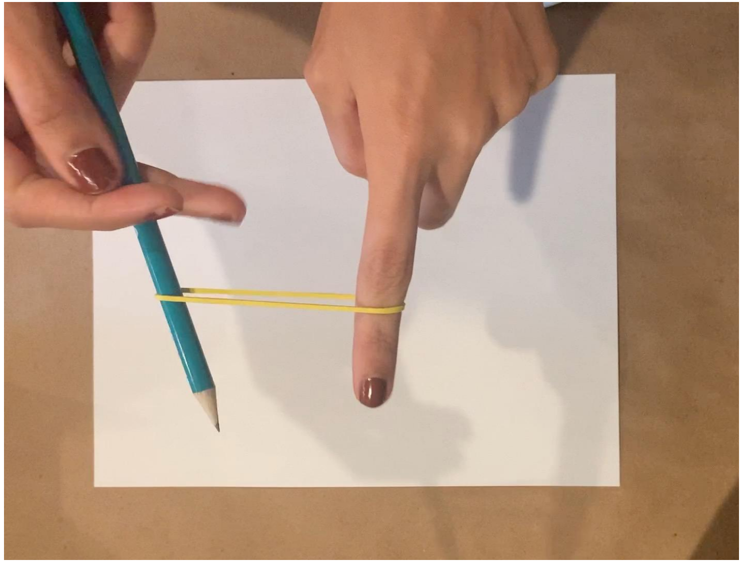
3. Rubber Band



RUBBER BAND

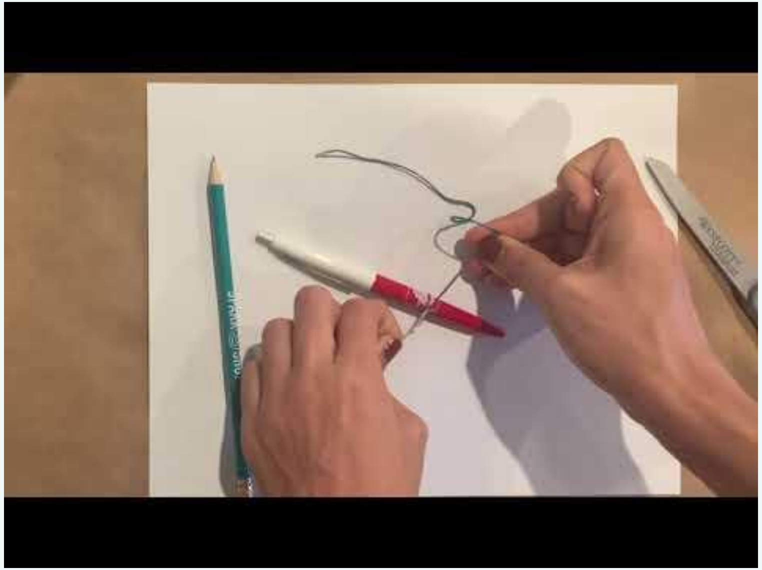
Think about the strengths and weaknesses of the rubber band method. Write at least two answers for each:

STRENGTHS	WEAKNESSES



4. String and pen

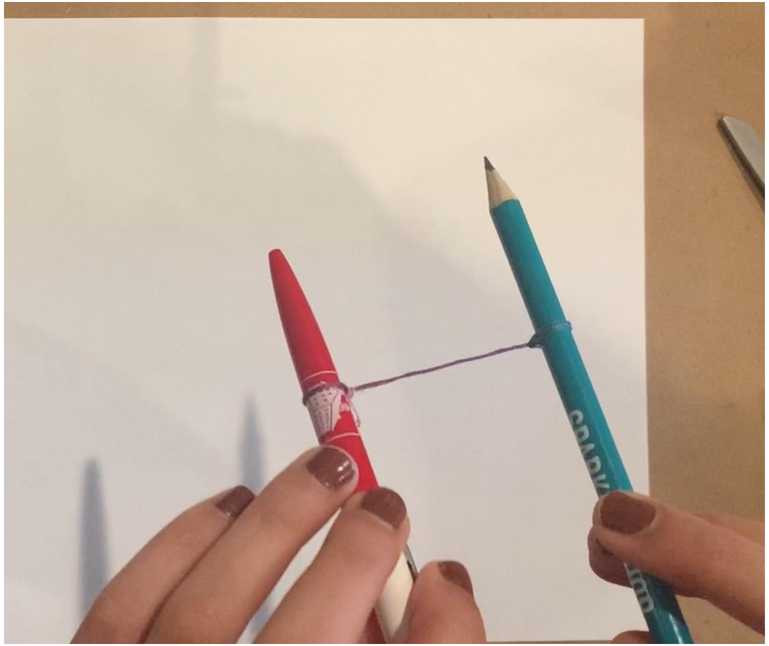
Follow the video to create 5 circles on a new piece of paper.



STRING AND PEN

Think about the strengths and weaknesses of the string and pen method. Write at least two answers for each:

STRENGTHS	WEAKNESSES



5. TRACING

On a new piece of paper, trace your Play-Doh lid to create circles.

COMPASS

Think about the strengths and weaknesses of tracing. Write at least two answers for each:

STRENGTHS	WEAKNESSES

COMPARING WITH CRITERIA

Criteria are measurable **characteristics**. All of the words to the right are examples of criteria.

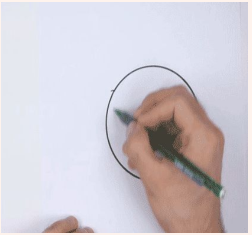
Every engineering problem has different criteria. They depend on which **requirements** the design has to meet.

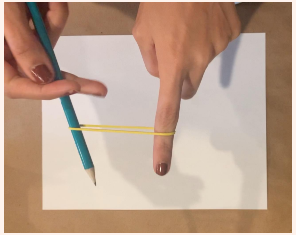
Sometimes it is most important for an **invention** to be safe, like if it's a medical tool. Other times, it's more important for an invention to look nice, like sunglasses.

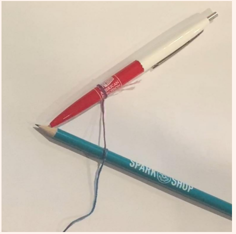
You're going to pick which process was best based on different criteria!

SIZE

Which process can you use to draw the largest circles?



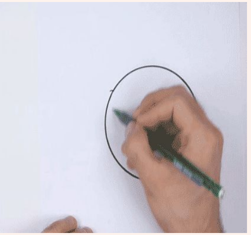


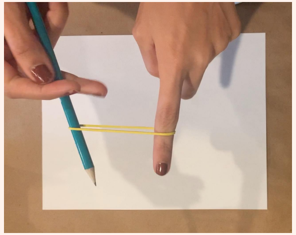


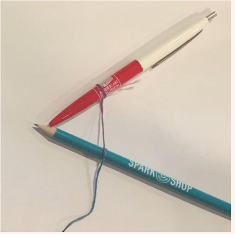
Explain why you chose your answer:

EASE

Which process was the easiest to follow?



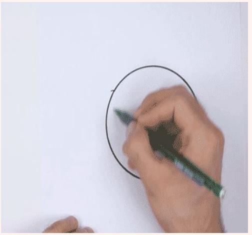


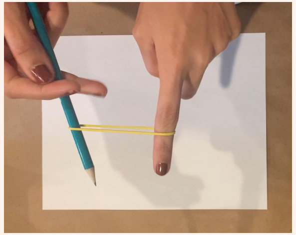


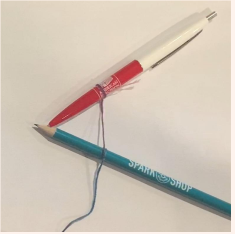
Explain why you chose your answer:

ADJUSTABILITY

Which process was best for creating different sized circles?



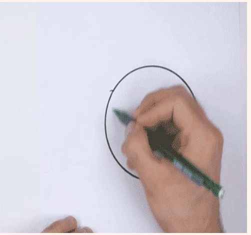


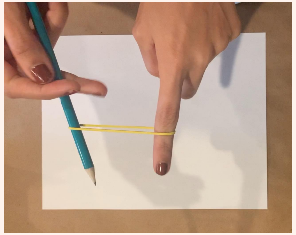


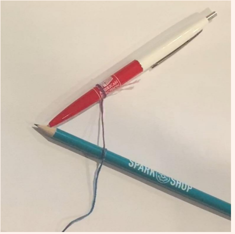
Explain why you chose your answer:

SPEED

Which process was best for drawing circles fastest?



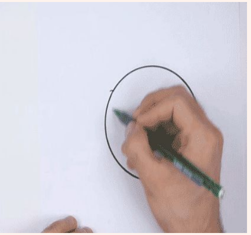


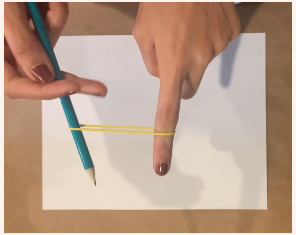
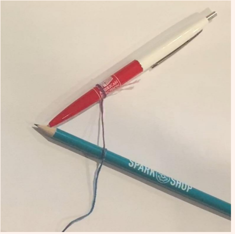


Explain why you chose your answer:

REPEATABILITY

Which process was the most repeatable, meaning it made precisely the same circle shape everytime?



Explain why you chose your answer:

REFLECTION

Which method of drawing circles was your favorite?

Based on your tests and your criteria, was one method of drawing a circle the best? How do you know?

CAREER SPOTLIGHT

MADISON RUBELI

SPARK SHOP

CAREER CONNECTION

Repeatability is important in a wide variety of jobs. It’s especially important for engineers and manufacturers to develop repeatable processes to create precise parts.

If you enjoy solving problems and are detail oriented, you might love a career like the one you’re about to explore!

You’ll meet Madison Rubeli, an engineer who designs parts that go on cars!

ACTIVITY

Meet Madison!

MADISON RUBELI

Click the video below to learn more about Madison:

SCAN ME

RECALL

What does Madison like about her job?

Why did Madison want to become an engineer?

REFLECT

If you could design something to be made in a factory, what would it be?

What are some skills you want to use in your future job?

TEACHER GUIDE

REPEATABILITY

SURVEY

This program is made possible by grant funding.

To keep this content free and accessible, please ask all participating students to fill out the surveys below so we can report back to our funders.

Pre-survey: https://forms.gle/xWQ5Xyca8VzcGH6m7

Post-survey: https://forms.gle/6NL2DZ6fkmhY8Jq17

SPARK SHOP

We are

ENGINEERS

In our materials, we will refer to your students as **engineers**

OVERARCHING THEME

In this unit, our overarching theme is **achieving repeatability**. Students will explore how repeatability in manufacturing makes our lives easier and safer. They will apply the engineering design process to create tools and processes that create repeatable results.

ESSENTIAL QUESTIONS

- **What do engineers and manufacturers do?**
  - What skills do engineers and manufacturers use?
  - Where do I see the work of engineers and manufacturers in my life?
- **Why is repeatability important?**
  - Why do STEM professionals care about repeatability?
  - What would life be like if processes weren't repeatable?
- **How do people create repeatability?**
  - How has this changed over time?
  - How can I create new tools and techniques that achieve repeatability?

UNIT STRUCTURE

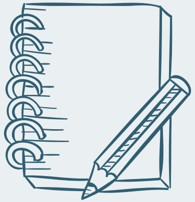
This interdisciplinary curriculum unit contains the following:

3 STEM LESSONS

These are **engineering-based** lessons and activities that explore a new phase of the design process

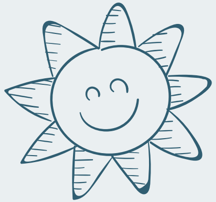
3 HUMANITIES CONNECTIONS

These are **arts, ELA, and social studies** lessons and activities that connect to the unit's STEM content



CAREER EXPLORATION

This is a spotlight on a STEM professional whose work applies the skills that students practice in this unit



MODIFICATIONS

Look at the **speaker notes** in the slides to view suggested modifications and extensions. Given how the school-structure is still evolving in the midst of the pandemic, **we have written this curriculum to be completely flexible based on your needs.** Instead of a summative assessment where students work on one project over the course of a unit, **each lesson will contain a "mini-project" that focuses on particular skills within the design process.** Below is how the curriculum can be adapted to your needs:

OCTOBER	UNIT 2: REPEATABILITY	
	LEARNING OUTCOME	**NGSS STANDARDS**
LESSON 1 Repeatability in Shoemaking History	Engineers will: • Explore the tools shoemakers use to create repeatable, complex shapes • Read about the shoe last preserved by APM • Explain why manufacturers strive for repeatability	• 3-5-ETS1-1
LESSON 2 Pen Deconstruction (STEM)	Engineers will: • Disassemble and reassemble pens to explore interchangeable parts • Define “manufacturing” and “assembly” • Infer why repeatability is an important criterion for manufacturers	• 3-5-ETS1-1
LESSON 3 Tessellation Cookie Cutters (STEM)	Engineers will: • Analyze examples of tessellations • Create an original tessellation on an interactive website • Create a “no waste” cookie cutter using metal material	• 3-5-ETS1-2 • 5-ESS3-1
LESSON 4 Repeatable Catapult (STEM)	Engineers will: • Define “repeatable,” “precise,” and “accurate” • Build and test a miniature catapult • Modify the catapult to improve repeatability	• 3-5-ETS1-2 • 3-5-ETS1-3

OCTOBER	UNIT 2: REPEATABILITY	
	LEARNING OUTCOME	**NGSS STANDARDS**
LESSON 5 Bill Of Materials (ELA)	Engineers will: • Deconstruct the pen once more, creating a detailed bill of materials • Give each part a unique name and create a simple drawing • Create a new bill of materials for a different assembly	• 3-5-ETS1-1 • 3-5-ETS1-2 • 3-5-ETS1-3 • 5-ESS3-1 • 4-ESS3-1
LESSON 6 Drawing Circles (Art)	Engineers will: • Use a variety of drawing tools to try to draw a perfect circle • Rank results by a variety of criteria (repeatability, ease, speed, accuracy, etc.) • Compare the abilities and limitations of each tool	• 3-5-ETS1-2 • 3-5-ETS1-3
LESSON 7 Career Spotlight: Jim Stokes	Engineers will: • Learn from a classic car restoration expert • Answer comprehension and reflection questions	• 3-5-ETS1-1 • 3-5-ETS1-2 • 3-5-ETS1-3 • 5-ESS3-1 • 4-ESS3-1

LESSON 1: REPEATABILITY IN SHOEMAKING (HISTORY)

SUMMARY:	Engineers will explore repeatability as a concept through a combination of readings and videos that show the evolution of shoe manufacturing technology.
OBJECTIVES:	• Define "engineer" and "manufacturer" • Interpret text, images, and videos about the history of shoemaking • Try to form pieces of paper into the shape of a foot • Describe how tools help people achieve repeatability.
CROSS-CONTENT STANDARDS:	• CCSS.ELA-LITERACY.RI.4.3 • CCSS.ELA-LITERACY.RI.4.4 • CCSS.ELA-LITERACY.RI.5.4 • CCSS.ELA-LITERACY.W.5.8 • CCSS.ELA-LITERACY.SL.5.2

AGENDA

1. **Warm-up** (5 mins)
   - Describe shape-making tools
   - Define repeatability, engineer, and manufacturer
2. **History of Shoe Manufacturing** (10 mins)
4. **Mini-Activity** (10-15 mins)
   - Students use paper to try to create a foot shape.
   - Compare different techniques in a discussion.
5. **Modern Shoe Manufacturing** (10 mins)
   - Learn about modern shoe making technology
   - Summarize how shoe manufacturing has changed over time.
6. **Exit Ticket** (5 mins)
   - What is a tool you use that helps you achieve repeatability?
   - How would life be different if manufacturers couldn't make processes repeatable?

MATERIALS NEEDED

- "1. Repeatability in Shoemaking (History)" slides
- At least 2 pieces of paper per students

LESSON 2: PEN DECONSTRUCTION (STEM)

SUMMARY:	Engineers will disassemble and reassemble pens to experiment with interchangeable parts.
OBJECTIVES:	• Define "assembly" • Deconstruct a pen and experiment with different reassembly challenges • Draw conclusions about why repeatability is an important goal for manufacturers.
NGSS STANDARDS:	• 3-5-ETS1-3
CROSS-CONTENT STANDARDS:	• CCSS.ELA-LITERACY.W.4.1.B • CCSS.ELA-LITERACY.W.4.2.D • CCSS.ELA-LITERACY.W.5.2.D

AGENDA

1. **Warm-up** (10 mins)
   - Deconstruct the first pen.
   - Reconstruct from the same parts.
   - Reflect.
2. **Mini-lesson** (5 mins)
   - Define "assembly."
3. **Application** (20 mins)
   - Deconstruct 2nd pen
   - Swap parts between pens and reassemble twice to meet different goals.
   - *Optional: Swap parts with classmates and reconstruct*
4. **Reflection** (5 mins)
   - Connection to industry: lego video
   - Reflection questions

MATERIALS NEEDED

- "2. Pen Deconstruction (STEM)" slides
- APM red and white pen
- SparkShop blue and orange pen

LESSON 3: NO WASTE COOKIE CUTTER (STEM)

SUMMARY:	Engineers will learn about tessellations. They will also create a tessellation cookie cutter using index cards, metal, and clay
OBJECTIVES:	• Analyze examples of tessellations • Define qualities of a tessellation • Create an original tessellation with an index card • Create a “no waste” cookie cutter using metal material
NGSS STANDARDS:	• 3-5-ETS1-1 • 3-5-ETS1-3
CROSS-CONTENT STANDARDS:	• CCSS.MATH.CONTENT.4.OA.C.5 • VA:Cr2.1.4 • VA:Cr1.1.4 • VA:Cr2.2.4a • VA:Cr2.2.5a

AGENDA

1. **Warm-up** (5 mins)
   - Look at examples of tessellations; what do students notice about the repeating patterns?
2. **Mini-lesson** (10-15 mins)
   - Look at examples of tessellations.
   - Learn about no waste cookie cutters.
3. **Application** (20 mins)
   - Using this link: http://www.shodor.org/interactivate/activities/Tessellate/ create a repeating tessellation.
   - Mold metal frame into a tessellation shape.
   - Test cookie cutter on clay.
   - Reflect on how to improve the prototype.

MATERIALS NEEDED

- “3. Tessellation Cookie Cutters (STEM)” slides
- Rolled tin
- Binder Clip
- Clay

LESSON 4: REPEATABLE CATAPULT (STEM)

SUMMARY:

Engineers will create and test a mini-catapult. Then, they will modify the catapult to hit a target with precision.

OBJECTIVES:

- Define “repeatability,” “precision“ and “accuracy”
- Build a mini-catapult
- Run a baseline test and gather data
- Modify the catapult to increase repeatability

NGSS STANDARDS:

- 3-5-ETS1-2
- 3-5-ETS1-3

CROSS-CONTENT STANDARDS:

- CCSS.ELA-LITERACY.RI.4.4
- CCSS.ELA-LITERACY.RI.5.4
- CCSS.ELA-LITERACY.W.4.8
- CCSS.ELA-LITERACY.W.5.8

AGENDA

1. **Warm-up** (10 mins): Compare targets game
2. **Mini-lesson** (10 mins)
   - Define repeatability, precision, and accuracy.
3. **Application** (30 mins)
   - Build mini-catapult
   - Run a test
   - Iterate and retest
   - Option: students can continue to iterate and retest for as long as you’d like.
4. **Exit Ticket** (5 mins)
   - Describe the improvements you made?
   - Why is it important for a catapult to be precise and accurate?

MATERIALS NEEDED

- “4. Repeatable Catapult (STEM)” slides
- “Achieving Repeatability” Material Kit Box
- 5 popsicle sticks
- 4 rubber bands
- 1 plastic spoon
- 1 styrofoam ball

LESSON 5: BILL OF MATERIALS (ELA)

SUMMARY:	Engineers will create a bill of materials for a product they deconstruct. (You can let them bring something from home with permission or something in the classroom that can be reassembled.)
OBJECTIVES:	• Deconstruct the pen once more, creating a detailed bill of materials • Give each part a unique name and create a simple drawing • Deconstruct a different object and create a new bill of materials
CROSS-CONTENT STANDARDS:	• 3-5-ETS1-2 • VA:Cr2.1.5a

AGENDA

1. **Warm-up** (5 mins)
   - Identify a product based on its bill of materials
2. **Mini-lesson** (10-15 mins)
   - Describe a bill of materials
   - Create a bill of materials for a pen
3. **Application** (20 mins)
   - Deconstruct another product and create a new bill of materials
4. **Reflection**(5 mins)

MATERIALS NEEDED

- "5. Bill of Materials (Writing)" slides
- Paper
- Something that students can take apart

LESSON 6: DRAWING CIRCLES (ART)

SUMMARY:	Engineers will attempt to draw precise circles using a variety of tools and techniques
OBJECTIVES:	• Test 5 different techniques/tools for drawing circles • Compare them based on different criteria
NGSS STANDARDS:	• 3-5-ETS1-3
CROSS-CONTENT STANDARDS:	• CCSS.ELA-LITERACY.W.4.1.B • CCSS.ELA-LITERACY.W.4.2.D • CCSS.ELA-LITERACY.W.5.2.D • VA:Cr2.1.4a • VA:Cr2.1.5a V

AGENDA

1. **Warm-up** (5 mins)
   - Why does repeatability matter to artists?
2. **Sketching** (15 mins)
   - Create 4 circles using each method presented.
   - Identify strengths and weaknesses of each technique.
3. **Comparison**(10-15 mins)
   - Describe criteria.
   - Compare the 5 techniques based on a variety of criteria.
4. **Exit Ticket** (5 mins)
   - Reflection

MATERIALS NEEDED

- "6. Drawing Circles (Art)" slides
- Pencil
- Pen
- Compass
- Rubber band
- String
- Play-doh
- 5 pieces of paper

LESSON 7: CAREER SPOTLIGHT

SUMMARY:	Engineers will be introduced to Jim Stokes, a mechanic and entrepreneur who restores classic cars. They will hear why Jim enjoys career and why precision and repeatability are key criteria for restoration projects.
OBJECTIVES:	• Define "restoration." • Explain why precision is important to a restoration professional. • Recall facts from the short video profiling Jim Stokes. • Reflect on why we restore things we care about.
CROSS-CONTENT STANDARDS:	• CCSS.ELA-LITERACY.RI.4.1 • CCSS.ELA-LITERACY.RI.5.1 • SEL 2A.2b.

AGENDA

1. **Warm-up** (5 mins)
   - Repeatability is an important goal in many careers. Call on students to explain why the professions listed on slide 2 connect to repeatability.
2. **Mini Lesson** (10 mins)
   - Define restoration.
   - Connect restoration to student's experience with questions on slide 4.
   - Watch the video profiling Jim Stokes.
   - Answer comprehension questions on slide 7.
   - Discuss the skills that Jim uses in his career as a mechanic and business owner.
3. **Exit Ticket** (10 mins)
   - Reflect on the questions on slide 8.
   - Either journal answers or discuss in small groups.

MATERIALS NEEDED

- "7. Career Spotlight" slides