Introduction

Welcome to Science F!

In this program, your students will build model landforms, observe microwave patterns, explore how much animals survive and adapt, provide nutrients to plants, and so much more.

The 36 experiments in this program will introduce your students to Energy, Waves, Biological Systems, Earth Systems, and Engineering Design. They are designed to teach your students to think like scientists and use real scientific skills and practices.

What do Students Need to Know?

In the past, science instruction focused on teaching students what we already knew about science. However, as technological growth and development exploded in recent years, we realized that simply teaching students what we know now isn't sufficient—it doesn't adequately prepare them for the future. The technology and scientific developments our students will use when they are adults have not been invented yet. So how do we prepare them for what they will need to know when it is still unknown to us?

Instead of teaching facts and knowledge, our instructional focus needs to shift. In addition to exposure to familiar science topics, such as Physical Science, Life Science, and Earth and Space Science, today's students also need skills, and scientific practices, that will help them find out what they need to know on their own. They need to become innovators and developers and not just passive consumers of scientific knowledge. By the time your students are ready for further education or to enter the workforce, they need to know how to investigate purposefully, build models, ask useful questions, and be able to report their findings so they can share what they learn with others. They should also be able to develop creative solutions to problems, and build and test their designs to determine how well they work. Once tested, they should be able to improve their designs so they can develop an even better solution. The lessons required to arrive at this destination will need to be hands-on, interactive, and student-driven. They may be a little noisy, and hopefully not too messy, but certainly an adventure like no other.

Introduction

How This Program Works

Through this program, your students will use the Scientific Method to explore their world, not just memorize the steps. Your students will brainstorm solutions to problems and have space to come up with ways to test them with you. Together, we will begin to prepare them to think for themselves, weigh the claims they encounter around them, and innovate on their own. We will also incorporate key Scientific and Engineering Practices to explore ideas that connect across all subjects, like cause and effect, patterns, structure and function, systems, stability and change, cycles, and more.

In addition to practicing the Scientific Method, you will also begin to teach the process of Engineering Design, in which students investigate a problem that can be solved through design. Some lessons will present a challenge or problem which will require your students to design (and build!) a solution, and then they will test their solution's effectiveness in solving the problem. From there, they may also apply what they learned from their tests toward designing an improved solution.

Science F will serve as your roadmap for this year's experiment instruction. We have chosen easy experiments that will fascinate your students and help them begin to develop key scientific skills through exploration. Before you start teaching, take a few minutes to familiarize yourself with this book and the structure of each experiment.

Each lesson begins with an overview of the **Key Concepts**, intended to give you, the instructor, a big-picture view of the goals of the lesson. By the end of the experiment and discussion, your students should have a solid understanding of the lesson's Takeaways (which mirror the Key Concepts), so you know they have mastered the important information. And since each lesson is truly an exploration, your students will often delve into elements of several different scientific disciplines in a single day.

Let's Get Started

To help you teach with confidence, we recommend you read through each experiment the night before. You may also use this time to gather the supplies noted on the **Materials List** from around your house, the Science Supplies Kit, or the Paper Packet. A few of the experiments require some early preparation, which we'll warn you about in a **Before You Begin** note at the start of the experiment. Be sure to check the next experiment for this note when you wrap up an experiment so you will be fully prepared to teach the next lesson when you intend to.

When you have gathered the supplies and are ready to teach, head to the experiment's **Introduction** and simply start reading to your students. Our provided instruction helps you pique your students' curiosity about each day's topic, and will challenge them to **Make a Prediction** about what they will experience in the experiment. The **Investigate** section offers step-by-step procedures that walk you through the experiment itself and includes discussion information to help you explain what's happening along the way. Use the questions under **Draw Conclusions** to bring the concepts and observations together, and close with the thoughts under **Takeaway**.

As you have time, enjoy the information under **See the Bigger Picture** which illustrates how the scientific principles discussed in the lesson apply to the world at large. Also, be sure to check out the **Make Connections** section as you work to add more depth and extend conversation about the experiment's topic. We also include **Tips** to help you know what to expect and complete the investigations with as few bumps as possible. If your students still want more, try out the suggestions under **Go Further** for related activities that will help you extend the exploration.

Plan for your students to take an active role in setting up the experiment and completing the steps (with your help, of course). Give them room to be curious and ask questions. If we don't address something that comes up as you work by the end of the experiment, make a note to help them find the answer later. The more you can support their curiosity and inquisitiveness, the better you will teach them to think like a scientist. And don't forget—they can help you clean up, too!

Introduction

Materials

While you will find some experiment supplies around your home, we have collected a number of materials for your convenience in our **Science Supplies Kit**, listed with a K in the Materials List. The Experiment Sheets, Design Planning Sheets, and Templates, listed with a P, follow each experiment and are also included in the **Paper Packet**.

The **Appendix** of this book includes a list of items in the Science Supplies Kit, a list of charts and templates in the Paper Packet, as well as a complete list of the supplies you will need to provide yourself. Start collecting those items now so they will be ready when you need them.

You are Ready to Begin!

We can't wait for you to start this grand adventure with your students, helping them to explore their world while learning to think like scientists and design like engineers. Through this journey, you will prepare them to be an active part of a future that we can't even imagine today.

Experiments

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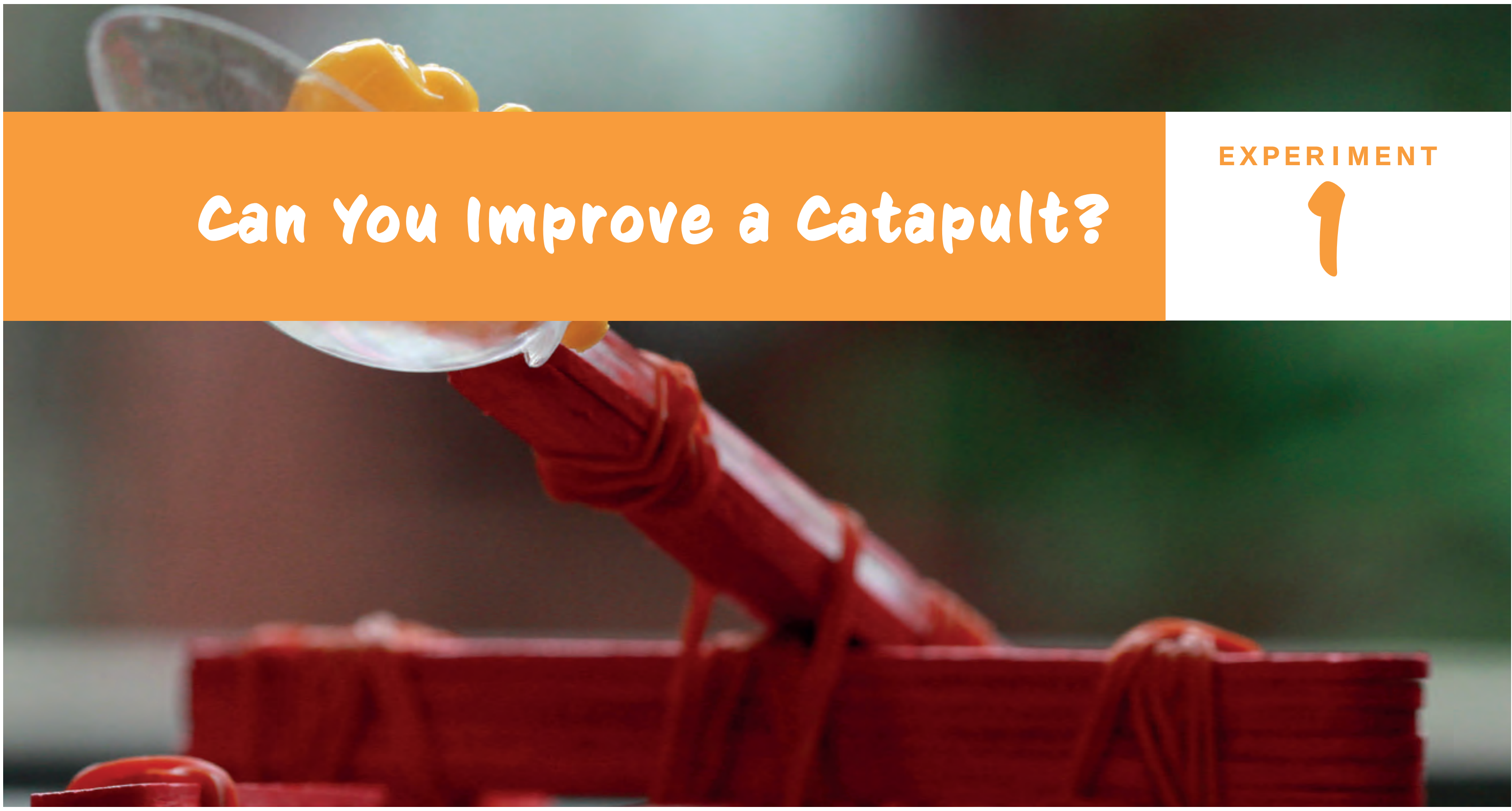


Can You Improve a Catapult?

EXPERIMENT 1

MATERIALS

- 12 popsicle sticks K
- 4 wide craft sticks K
- 2 straight straws K
- 2 wooden skewers K
- 2 clothespins K
- 2 rubber bands K
- 2 paper condiment cups K
- masking tape K
- a ping pong ball K
- **Can You Improve a Catapult? Design Planning Sheet #1** P
- a hot glue gun with glue sticks (or regular craft or school glue)
- 6 small paper cups
- a ruler or measuring tape
- additional popsicle sticks, straws, rubber bands, plastic spoons, or other materials you have at home

K Indicates the item is in the Supply Kit.

P Indicates the item is in the Experiments Paper Packet.

Key Concepts

- Catapults use stored energy, also known as potential energy, to move objects.
- The stored energy from the catapult transforms into kinetic energy that makes an object move.
- Engineers can design machines that transform energy from potential to kinetic. A **machine** is a device that makes work easier.
- Engineers test their machines and improve their designs based on the results from their tests.

Introduction

Have you played with a catapult? Large catapults were invented for war in ancient times. A machine could throw rocks at a wall with greater force than a person could. The first catapults used the design of a crossbow and arrow on a large swinging arm.

Early Catapult - Like a Large Crossbow

Later Catapult - Uses Arm to Launch

The engineers designed these machines to efficiently throw rocks over a long distance with enough force to take down city walls. In this experiment, you will work as an engineer to design the best possible catapult to knock down a wall of small paper cups.

Both catapults and slingshots use the same principle. When you pull a slingshot back with a rock in it, you store energy. This stored energy is called **potential energy**. When you release the slingshot, the potential energy transforms into **kinetic energy**, or moving energy. This kinetic energy propels the rock forward.

Engineers use a standard process to solve problems. They start by identifying the problem they want to solve. Then, they write down or sketch out their ideas and use these drawings or designs to build or create a possible solution to the problem. Once they have a prototype built, they try it out. After testing their prototype, they reflect on how it worked and how well it solved the problem. Then, they think of ways to improve it. They change the prototype to improve it, and they try it again.

The engineering design process involves six basic steps:

1. **Ask** a question that needs to be solved.
2. **Explore** and imagine solutions to the problem.
3. **Plan** a design of a prototype (a first model of your solution).
4. **Create** the prototype.
5. **Test** the prototype.
6. **Improve** the prototype by making changes to the design. (And then test again!)

You will build and test a design we provide, and identify some design issues it has. You will then design your own catapult, test it, improve it, and test it again.

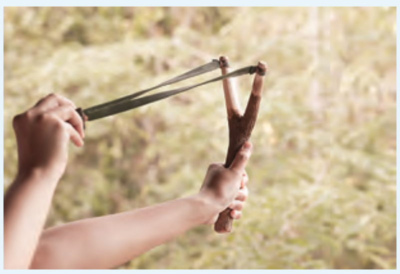
Remember: Potential energy is stored energy. Kinetic energy is energy in motion.

Point to Ponder

How can you store enough energy in your catapult so that you can throw an object forward, and knock down a wall?

Did You Know?

Two other weapons similar to catapults are slingshots and trebuchets. A slingshot builds up potential energy when its elastic material, holding an object, is pulled back. When the object is released, potential energy rapidly transfers into kinetic energy and sends the projectile flying.



Slingshot - Uses Elastic Material

A trebuchet ties a projectile to one side of a lever and has a counterweight on the opposite side. A trigger holds the counterweight in place. When the trigger is released, the counterweight falls and slings the projectile up and over.

Trebuchet - Uses Counterweight

Investigate

First, you will build and test a simple catapult. Your goal will be to knock down a wall of cups.

1. Glue a clothespin near one end of a wide craft stick.

Tip: We recommend you use a hot glue gun to glue the materials together. Hot glue dries quickly and holds well. You may also use regular craft or school glue, but will need to add time for the glue to dry completely before using your catapult.

2. Glue another wide craft stick on top of the clothespin. Line up the ends of the two craft sticks.

3. Glue a condiment cup to the top craft stick, about 2 cm ($3/4^{th}$ of an inch) away from the other end of the craft stick.

4. Allow glue to completely dry.

5. Place a ping pong ball inside the cup.

6. Make sure it works: Push down the upper craft stick and release it to throw the ball forward. You may need to use your other hand to stabilize the base.

7. Build a wall using six small paper cups.

8. Place the catapult about 1 meter (3 feet) away from the wall of cups.

9. Release a ball from the catapult in the direction of the wall of cups.

10. Record your results using the criteria on **Design Planning Sheet #1**.

Identify the Problem

Now you will analyze the first catapult's design and begin the engineering process to create a better catapult.

11. Analyze the criteria found on the **Design Planning Sheet** for the first simple catapult. What problems do you notice in its design? Could you improve the design to meet more criteria? Record your thoughts on the **Design Planning Sheet #1.**

Explore

12. With adult permission, gather materials from around your house to create a catapult. What do you have available? What are the characteristics of these materials? How can these materials be used to build a catapult? Consider where potential energy was stored in the first simple catapult. Can any of your materials store potential energy?

13. Make a list of the materials you might use on the **Design Planning Sheet #1.**

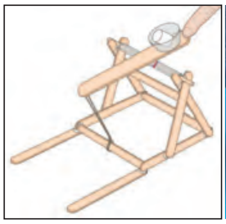
Teacher: Provide students with a variety of materials so they can choose the ones they think will best solve the problem. Use office supplies, clean items from the recycling bin, or craft items.

Possible materials:
craft sticks
rubber bands
clothespins
wooden skewers
interlocking bricks
straws
plastic spoons
pencils
cardboard
plastic food containers
any other craft materials you have at home

Design

14. Draw a sketch of your design for a catapult on Design Planning Sheet 1. Label the materials you will use, and point to where the potential energy is stored. You can make improvements to the basic model you built, or you can make something completely different and new. Make sure your catapult includes an arm that can be pulled back and a cup to hold a small ball.

Engineers get inspiration from nature and other inventions. Review the pictures of the catapults, the slingshot, and the trebuchet in the Introduction. Look for inspiration in the designs below.


Teacher: If your students have trouble generating ideas for a design, you can ask prompting questions such as: What would happen if you added another clothespin to the design? Could you reproduce the clothespin design with other materials that you have available? What happens if you place the catapult on top of a book? Could you lift the catapult using other available materials?

Create

15. Use your sketch and materials to build your own catapult.

Try It Out

16. Test your prototype three times; use the ping pong ball to knock down the wall of cups from 1m (3ft) away. Record your observations on the **Design Planning Sheet #1**.

Improve

17. Analyze how well your prototype met the criteria. How could you improve your design to make your catapult more successful at knocking down the wall? If your catapult is not strong enough, what could you add to make it stronger? How could you store more energy? Think about a slingshot and the difference it makes if you pull it farther back. How can you ensure the ball travels forward instead of up? Try changing the angle of the arm. If your catapult is not stable enough, could you build a wider base for it or use tape instead of glue?

18. Draw a picture on the **Design Planning Sheet #1** of the changes you would make to improve your catapult design. Explain your improvements and why you decided to make those changes.

19. Build your improved prototype.

Try It Out—Take 2

20. Test and recored your results. Place your catapult 1 m (3 feet) away from the wall of cups and launch the ball.

Draw Conclusions

- What materials did you choose for your designs? Why did you choose those materials? (Answers will vary. Possible: The craft sticks were chosen because they are strong and stable; the rubber bands were chosen because they are flexible and can store energy as they stretch; the clothespins were chosen because they have a spring that can store energy.)
- What makes the ball go farther? (Answers will vary. Possible: The ball can go farther by adding more rubber bands so more energy can be stored, changing the angle at which the ball is thrown, and making the arm longer.)
- How did you revise your last design based on what you learned from your previous tests? Why? (Answers will vary.)

Make Connections

Although catapults were used to conquer castles during the Middle Ages, they have been used long before castles appeared in history. Many different cultures used some variation of catapults over many centuries. Archaeologists believe that catapults were first used in China in the 3rd and 4th Century BCE. These functioned similarly to a long crossbow, but with a swinging arm.

Takeaway

Catapults are machines. Machines make work easier for people. Many designs of catapults exist throughout history, but most designs use stored potential energy to create moving kinetic energy to launch objects towards walls. Some designs threw objects accurately; other designs excelled at throwing objects farther. Machines, like catapults, help us accomplish tasks. By exploring the world around us, learning from what others have done, testing our ideas, recording and analyzing what happens, and iterating on our prototypes, we can end up with some pretty amazing tools and do more than we did in the past.

Engineers find real-life problems and develop machines or tools to fix the problems, and make life easier for people. They must use their understanding of physical science to make their designs. Then, engineers test and analyze their designs and improve them so they function better and achieve their intended goals.

See the Bigger Picture

Armies no longer use catapults as weapons, but the physical mechanism of a catapult can be applied for other purposes. For example, an aircraft catapult launches airplanes from the deck of a ship without a long runway.

GO FURTHER

Think of some modern machines around you and, with an adult's permission, research how they have changed over time. For example, how has the design of cars or airplanes changed and improved over time?

Can You Improve a Catapult?

DESIGN PLANNING SHEET 1

Investigate: Record the results of the simple catapult design using the criteria below:

Did the catapult stay together or break apart?

Did the ball travel in the correct direction?

Did the ball travel 1 meter (3 feet)?

Did the ball fly at an appropriate height to hit the wall?

How many cups did the ball knock over?

Other observations:

Identify the Problem: What design issues do you find in the simple catapult design?

Explore: What materials do you have available? What are the characteristics of these materials? How can these materials be used to build a catapult?

Design: Draw a picture of your design for a catapult. Label the materials you will use. Make sure you include an arm and a cup.

Try It Out:

	Trial 1	Trial 2	Trial 3
Did the catapult stay together or break apart?			
Did the ball travel in the correct direction?			
Did the ball travel 1 meter (3 feet)?			
Did the ball fly at an appropriate height to hit the wall?			
How many cups did the ball knock over?			
Other observations:			

Improve: Draw a picture of the changes you would make to your catapult design to improve it.

Try It Out—Take 2:

	Trial 1	Trial 2	Trial 3
Did the catapult stay together or break apart?			
Did the ball travel in the correct direction?			
Did the ball travel 1 meter (3 feet)?			
Did the ball fly at an appropriate height to hit the wall?			
How many cups did the ball knock over?			
Other observations:			