DISCOVERY ENGINEERING IN PHYSICAL SCIENCE

Case Studies for Grades 6–12

M. GAIL JONES • ELYSA CORIN • MEGAN ENNES
EMILY CAYTON • GINA CHILDERS

NSTApress
National Science Teachers Association

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Arlington, Virginia

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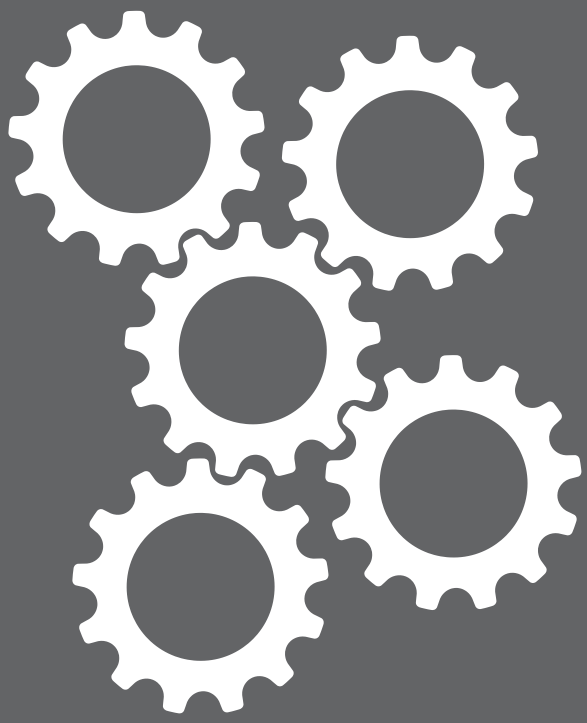
1840 Wilson Blvd., Arlington, VA 22201
www.nsta.org/store
For customer service inquiries, please call 800-277-5300.

22 21 20 19 4 3 2 1

Library of Congress Cataloging-in-Publication Data
Names: Jones, M. Gail, 1955- author.
Title: Discovery engineering in physical science : case studies for grades 6-12 / M. Gail Jones [and four others].
Description: Arlington, VA : National Science Teachers Association, [2019] | Includes bibliographical references.
Identifiers: LCCN 2018046696 (print) | LCCN 2018049966 (ebook) | ISBN 9781681406183 (e-book) | ISBN 9781681406176 (print)
Subjects: LCSH: Discoveries in science--Study and teaching (Elementary)--Activity programs. | Discoveries in science--Study and teaching (Middle school)--Activity programs. | Discoveries in science--Study and teaching (Secondary)--Activity programs. | Engineering--Study and teaching (Elementary)--Activity programs. | Engineering--Study and teaching (Middle school)--Activity programs. | Engineering--Study and teaching (Secondary)--Activity programs. | Science--Study and teaching (Elementary)--Activity programs | Science--Study and teaching (Middle school)--Activity programs. | Science--Study and teaching (Secondary)--Activity programs.
Classification: LCC Q180.55.D57 (ebook) | LCC Q180.55.D57 D57 2019 (print) | DDC 507.1/2--dc23
LC record available at *https://lccn.loc.gov/2018046696*

This book is dedicated to all the youth who remind us that the smallest things can be the most important.

Contents



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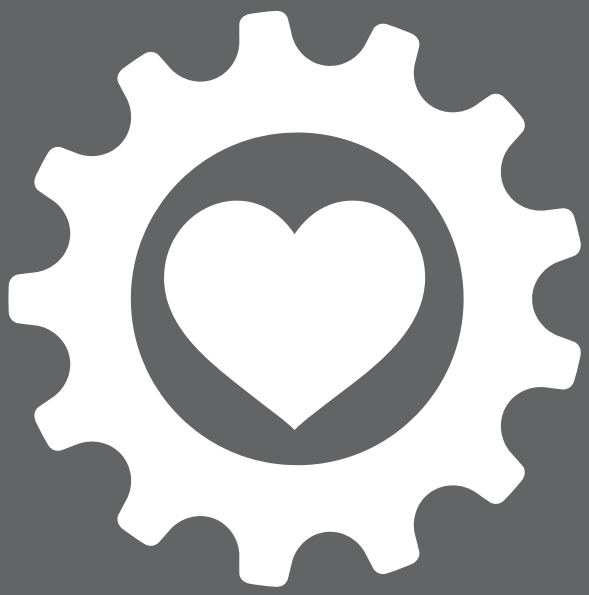


Acknowledgments

The authors wish to thank the many people who inspired, reviewed, and helped craft this book. Our special gratitude goes to Sabrina Monserate, Laurel McCarthy, Kendall Rease, and Joseph Gaiteri. We also want to recognize the contributions of Rebecca Hite and thank her for getting us interested in using case studies to teach science. Finally, we thank the teachers who have piloted the book's activities and given us feedback.

22

VELCRO

Engineering Mimics Nature

A Case Study Using the Discovery Engineering Process

Introduction

Imagine a world without zippers, buttons, or Velcro to fasten your clothing. Throughout history, people have designed new ways to keep clothing closed and fitting comfortably. The discovery of Velcro changed the way clothes, shoes, and even suitcases and purses open and close. Velcro is a unique type of hook and loop tape that was inspired by cockleburs in nature. (Cockleburs [Figure 22.1] are seeds covered by hard, curved spines that are difficult to remove if they become hooked onto clothing.) This type of engineering in which objects in nature are used as models for new products is known as biomimicry.

FIGURE 22.1

Cocklebur

Lesson Objectives

By the end of this case study, you will be able to

- Describe the hook-and-loop system that makes up Velcro.
- Analyze how hook-and-loop tape functions to keep materials together and how it is able to repeatedly open and close.
- Design a new application for hook-and-loop tape.

The Case

Read the following description of how Velcro was discovered.

One day in the 1940s, George de Mestral was hunting in the Jura Mountains of Switzerland when he observed that his pants were coated with little cockleburs. He checked his dog and noticed that the dog's fur was covered with cockleburs, too. De Mestral was intrigued by the idea that these little seed pods could stick to his pants so effectively. When he returned to work, he looked at one of the cockleburs under a microscope and saw that tiny hooks on the seed pod were looped into the threads on his pants.

Typically about an inch long, the most common type of cocklebur is from the plant *Xanthium strumarium.* Just one plant can produce many of these spine-covered burs. A single bur contains two seeds that are carried to different areas by animals that happen to bump up against the plant. The cocklebur sticks to the animal's fur until it is dislodged at some point during the animal's wanderings. This mechanism allows for the scattering of cocklebur seeds. And due to the way in which its seeds get dispersed, the cocklebur has been nicknamed "nature's hitchhiker."

Once de Mestral saw the cocklebur hook under his microscope, he decided to make a new type of fastener that mimicked the hooks on the bur and the fibers of his pants. He called this new hook-and-loop fastener Velcro, which is a combination of the words *velvet* and *crochet*. De Mestral went on to obtain a patent in Switzerland for his new fastener, and he began to sell Velcro in the United States in the 1950s. Over the years, Velcro has become a popular feature on shoes, coats, and other products.

Recognize, Recall, and Reflect

1. Why was George de Mestral so fascinated by the cockleburs he and his dog had come across while hunting in the mountains?
2. How does Velcro mimic a cocklebur?
3. What words were combined to make the word *Velcro*?

Investigate

In this activity, you will explore how hook-and-loop tape like Velcro works to fasten things together.

Materials

For each group of students:

- 1 in. strip of hook-and-loop tape
- Video microscope or dissecting microscope
- Different samples of fabric such as velvet, wool, and cotton

Safety Note: Do not handle wool if you are allergic to it. Wash your hands with soap and water immediately after completing this activity.

Create, Innovate, and Investigate

- Begin by observing the two different parts of the hook-and-loop tape. What do you notice about each part?
- Bend each piece of the tape and notice what happens to the piece with hooks.
- Try dragging the hooked tape across different fabrics such as velvet, a piece of wool, and a cotton sock. What do you observe?
- Watch what happens when you pull the hooks away from the different fabrics. Do the hooks bend? Do they break?
- Repeatedly scrape the hooks on a fabric to determine whether they lose the ability to fasten.

Questions for Reflection

1. What did you observe about hook-and-loop tape?
2. Is hook-and-loop tape equally effective in sticking to different types of fabric?

Apply and Analyze

How does Velcro work? The product is composed of two pieces of tape. One piece is covered with small hooks and the other piece is covered with small loops. As the two pieces of tape come together, the hooks connect with the loops, creating a bond. When the tape is pulled apart, the hooks flex and release the loops.

A new product designed by 3M Company uses a similar type of fastener with interlocking strips. But instead of having hooks or loops, both of the fastener's strips feature small, flexible pins that are shaped like mushrooms. The pins lock together when the two strips are pressed into each other. This new fastener is called Dual Lock fastener, and the makers of the product claim that it is stronger than Velcro. Find out more about these two fasteners by reviewing the sources listed below. Then answer the questions that follow.

Online Sources

- How does Velcro work?
  www.youtube.com/watch?v=mgcIivxODH0
- Velcro, observed under video microscope
  www.youtube.com/watch?v=62jhQNyPm3s
- 3M Scotch Extreme Dual Lock Fasteners review
  http://toolguyd.com/scotch-extreme-fasteners-review

1. What are the limitations of these types of fasteners when it comes to clothing?
2. How do you think the cost of Velcro compares to that of zippers or buttons?
3. Does Velcro last forever? What happens to it over time?
4. What is the advantage of a fastener with mushroom-shaped pins over a fastener with hooks and loops?
5. How could you design an experiment that would allow you to measure the strength of each of these fasteners?

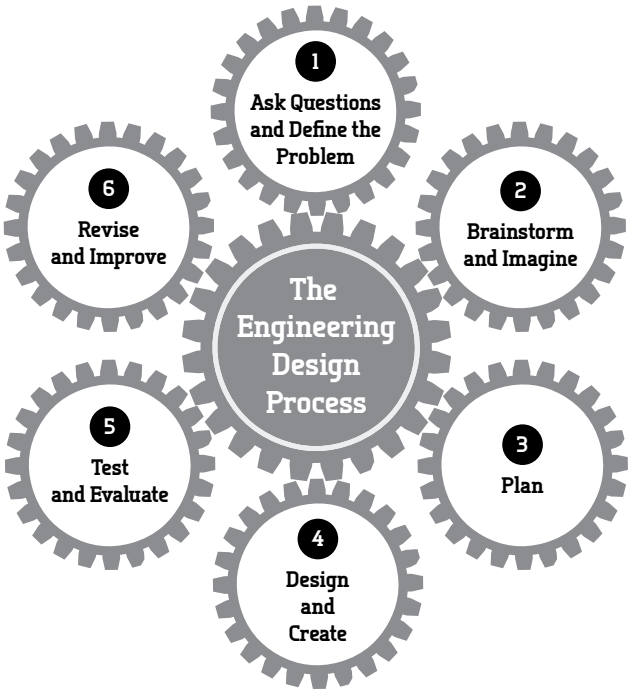
Design Challenge

Engineering is the application of scientific understanding through creativity, imagination, problem solving, and the designing and building of new materials to address and solve problems in the real world. You will be asked to take the science you have learned in this case and design a process or product to address a real-world issue of your choosing.

Engineers use the engineering design process as steps to address a real-world problem (see Figure 22.2). You will now use this process as you come up with a new way to use hook-and-loop tape. In this case, you are asking the question (Step 1) of how you can design a new use for hook-and-loop tape. Drawing on your creativity, you will then brainstorm (Step 2) a new product that uses hook-and-loop tape to solve a problem. Afterward, you will create a plan (Step 3) for this new product. Next, you will create a sketch and/or model of your product (Step 4). Then, you will work with your classmates to think about how you would test (Step 5) and refine (Step 6) your product.

FIGURE 22.2

The Engineering Design Process



1. Ask Questions

Hook-and-loop tape serves many other purposes aside from being a fastener for clothing and shoes. For instance, the product can be used to hold down rugs, keep electrical cords coiled up, attach a remote control to a television, and much more. Based on your previous observations and research, consider a new problem that may be addressed or product that could be created using hook-and-loop tape. What are situations in which you would need to fasten objects together—and also easily be able to pull them apart? What problems could you solve using hook-and-loop tape?

2. Brainstorm and Imagine

Brainstorm a specific application for hook-and-loop tape that could help solve a problem. (For example, one idea is to use this tape to hold crib bumpers in place on the edge of a baby crib. Another idea is to use a biodegradable and edible type of hook-and-loop tape with food displays and tall, elaborate cakes.)

3. Create a Plan

Create a plan for your product. Consider: (1) What is the purpose of your product? (2) What are benefits to using your product? (3) What are the limitations of your product? Use the Product Planning Graphic Organizer to help you.

4. Design and Create

Consider the following questions and considerations for your product and its design.

- How would incorporating hook-and-loop tape into your design make the product better?
- How would you overcome any limitations or drawbacks caused by using hook-and-loop tape in your design?
- What technologies might need to be developed to create or manufacture this design?
- What are any constraints or drawbacks you can foresee with implementing this design?
- Would there be any safety concerns regarding your product?

Create a sketch of your product design. Make sure your design incorporates your previous research and exploration.

5. Test and Evaluate

Working with your classmates, come up with a way to test your design to see its effectiveness.

6. Revise and Improve

Give your plans to one of your classmates for review. Listen to his or her feedback on your design. What are some ways you can use the input to refine your design? Take some time to revise and make improvements.

Reflect

1. What technologies might need to be developed to create or manufacture this design?
2. What are any constraints or drawbacks you can foresee with implementing this design?
3. Would there be any environmental or human health concerns about this design?

Product Planning Graphic Organizer

Proposed Product Idea	
Pros (Benefits)	**Cons (Limitations)**

TEACHER NOTES

VELCRO

ENGINEERING MIMICS NATURE

A Case Study Using the Discovery Engineering Process

Lesson Overview

In this lesson, students explore Velcro and similar products that can be used to keep clothes and other objects fastened together. Velcro was an accidental discovery that has led to a number of new applications and products.

Lesson Objectives

By the end of this case study, students will be able to

- Describe the hook-and-loop system that makes up Velcro.
- Analyze how hook-and-loop tape functions to keep materials together and how it is able to repeatedly open and close.
- Design a new application for hook-and-loop tape.

The Case Study Approach

This lesson uses a case study approach. Explaining the purpose of case studies will encourage your students to relate to the material and engage with the problem. At the heart of each case study in this book is a true story, one that describes how someone in his or her everyday life or during a routine workday made an observation or did a simple experiment that led to a new insight or discovery. Case studies are designed to get students actively engaged in the process of problem solving. The narrative of the case supplies authentic details that place the student in the role of the inventor and provide scaffolds for critical thinking and deep reflection. A case is more than a paragraph to read or a story to analyze but rather a way of framing problems, synthesizing what is known, and thinking creatively about new applications and solutions. In this lesson, students consider how Velcro was discovered and work together to think about new applications for hook-and-loop tape to solve real-life problems.

Use of the Case

Due to the nature of these case studies, teachers may elect to use any section of each case for their instructional needs. The sections are sequenced in order (scaffolded) so students think more deeply about the science involved in the case and develop an understanding of engineering in the context of science.

Curriculum Connections

Related Next Generation Science Standards

PERFORMANCE EXPECTATIONS

- HS-ETS1-2. Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.
- HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

SCIENCE AND ENGINEERING PRACTICES

- Analyzing and Interpreting Data
- Engaging in Argument From Evidence
- Constructing Explanations and Designing Solutions

Related National Academy of Engineering Grand Challenge

- Engineer the Tools of Scientific Discovery

Lesson Preparation

You will need to make copies of the entire student section for the class. Students will need internet access at various points in the lesson. Alternatively, you can project videos or print and distribute copies of online content for the class. For the Investigate section, you will need hook-and-loop tape. Sources for this material include fabric stores, hardware stores, and online shops. Look at the Teaching Organizer (Table 22.1, p. 372) for suggestions on how to organize the lesson.

Materials

For each group of students:

- 1 in. strip of hook-and-loop tape
- Video microscope or dissecting microscope
- Different samples of fabric such as velvet, wool, and cotton

Safety Note for Students: Do not handle wool if you are allergic to it. Wash your hands with soap and water immediately after completing this activity.

Time Needed

55 minutes

TABLE 22.1

Teaching Organizer

Section	Time Suggested	Materials Needed	Additional Considerations
The Case	5 minutes	Student packet	Could be read in class or as a homework assignment prior to class
Investigate	10 minutes	Student packet, 1-inch strip of hook-and-loop tape, video microscope or dissecting microscope, different samples of fabric such as velvet, wool, and cotton	Recommended as a small-group investigation
Apply and Analyze	10 minutes	Student packet, internet access	Whole-class activity or done individually
Design Challenge	30 minutes	Student packet	Small-group activity

Teacher Background Information

There are a number of resources and videos about hook-and-loop tape available on the internet. You may want to observe the behavior of hook-and-loop tape on sites such as YouTube prior to using the case.

Vocabulary

- biomimicry
- cocklebur
- fastener

Teacher Answer Key

Recognize, Recall, and Reflect

1. **Why was George de Mestral so fascinated by the cockleburs he and his dog had come across while hunting in the mountains?**

   He was intrigued by how effectively these seed pods clung to his pants.

2. **How does Velcro mimic a cocklebur ?**

   Part of the fastener has hooks that are modeled after the hooks on a cocklebur.

3. **What words were combined to make the word *Velcro*?**

   Velvet and crochet

Questions for Reflection

1. **What did you observe about hook-and-loop tape?**

   Answers will vary.

2. **Is hook-and-loop tape equally effective in sticking to different types of fabric?**

   No. Students should note that the tape generally sticks best to fabrics such as wool. It sticks less effectively to fabrics like cotton.

Apply and Analyze

1. **What are the limitations of these types of fasteners when it comes to clothing?**

   Answers will vary but may include that the small hooks on hook-and-loop tape can scratch or irritate skin. Also, hook-and-loop tape doesn't close two materials as tightly as other fasteners like buttons. Furthermore, the pressure that is needed to connect the hooks and loops of the fastener sometimes results in wrinkles.

2. **How do you think the cost of using Velcro compares to that of zippers or buttons?**

All three fastener systems can be made of synthetic materials and the cost is similar. Natural buttons or metal zippers could result in a costlier system.

3. **Does Velcro last forever? What happens to it over time?**

   If used over and over again, the hooked side of hook-and-loop tape can become entangled with fibers, hair, and other debris, making it difficult to maintain a tight connection with the looped side of the fastener.

4. **What is the advantage of a fastener with mushroom-shaped pins over a fastener with hooks and loops?**

   Students should note that the pins will not catch other materials (like a hair or fiber) as easily as a hook-and-loop system would.

5. **How could you design an experiment that would allow you to measure the strength of each of these fasteners?**

   Answers will vary, but students might suggest adding weights to pieces of material or fabric held together by the different fasteners to see how quickly each fastener comes undone under the stress of the weight.

Reflect

1. **What technologies might need to be developed to create or manufacture this design?**

   Answers may vary depending on the students' designs.

2. **What are any constraints or drawbacks you can foresee with implementing this design?**

   Answers may vary depending on the students' designs.

3. **Would there be any environmental or human health concerns?**

   Answers may vary depending on the students' designs.

Assessment

The Design Challenge can be assessed using the rubric in the appendix (p. 377).

Extensions

This lesson can be followed with lessons about the elasticity and adhesive properties of different types of glues. You can cover this topic with other cases in this book

as well, including the case study in Chapter 10, "A Sticky Discovery: The Invention of Post-It Notes" (p. 153) and the case study in Chapter 17, "Super Glue: Accidentally Discovered Twice" (p. 269).

Resources and References

3M Industrial Assembly and Design. 2010. "3M™ Dual Lock™ Reclosable Fasteners: Bowling ball test." YouTube video. *www.youtube.com/watch?v=heavjPsXF1w.*

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Design Squad Global. 2014. "How does Velcro work?" YouTube video. *www.youtube.com/watch?v=mgcIivxODH0.*

ToolGuyd. 2015. 3M Scotch Extreme Dual Lock Fasteners review. *http://toolguyd.com/scotch-extreme-fasteners-review.*

Index

Note: Page references in **boldface** indicate information contained in figures or tables.

"A number of amazing innovations have resulted from someone making an observation of a phenomenon or trying an experiment just to 'see what will happen.'"

—From the introduction to *Discovery Engineering in Physical Science*

DISCOVERY ENGINEERING IN PHYSICAL SCIENCE

Case Studies for Grades 6–12

Show your students how amazing it can be to just "see what will happen" when they blend science, engineering, and serendipity. Focusing on innovations sparked by accidental observations, the case studies in this resource are a lively way to integrate engineering and experimentation into your physical science classes. Middle and high school students will learn fundamental science processes while using their natural curiosity to explore ideas for new engineering applications and products. They'll also find out that gecko feet inspired scientists to develop a stickier adhesive, cockleburs in dog fur led to Velcro, and the invention of safety glass was a total accident.

The book's 22 easy-to-use investigations help you do the following:

- **Use real-world case studies to bring accidental inspiration to life.** Each investigation starts with an actual scientific discovery that students explore through primary documents or historical accounts.
- **Let students be the innovators.** The investigations task your classes to investigate physical materials, do research, examine data, create models, and use their own personal ideas to design new products or problem-solving applications.
- **Apply the content in flexible, interesting ways.** You can implement the investigations in part or as a whole, and you can use them to teach one or more science concepts while exposing students to the unpredictable nature of science. Students will be intrigued by investigations with titles such as "By the Teeth of Your Skin: Shark Skin and Bacteria" and "From Ship to Staircase: The History of the Slinky."

Discovery Engineering in Physical Science is not only ideal for the classroom but also perfect for informal education at STEM camps, science centers, and more. You'll help your students see that just as there is not one way to do science, there are many paths that lead to innovations in engineering. And who knows what might happen? Maybe your students will engineer the next amazing designs inspired by gecko feet!

Grades 6–12

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PB444X1
ISBN: 978-1-68140-617-6