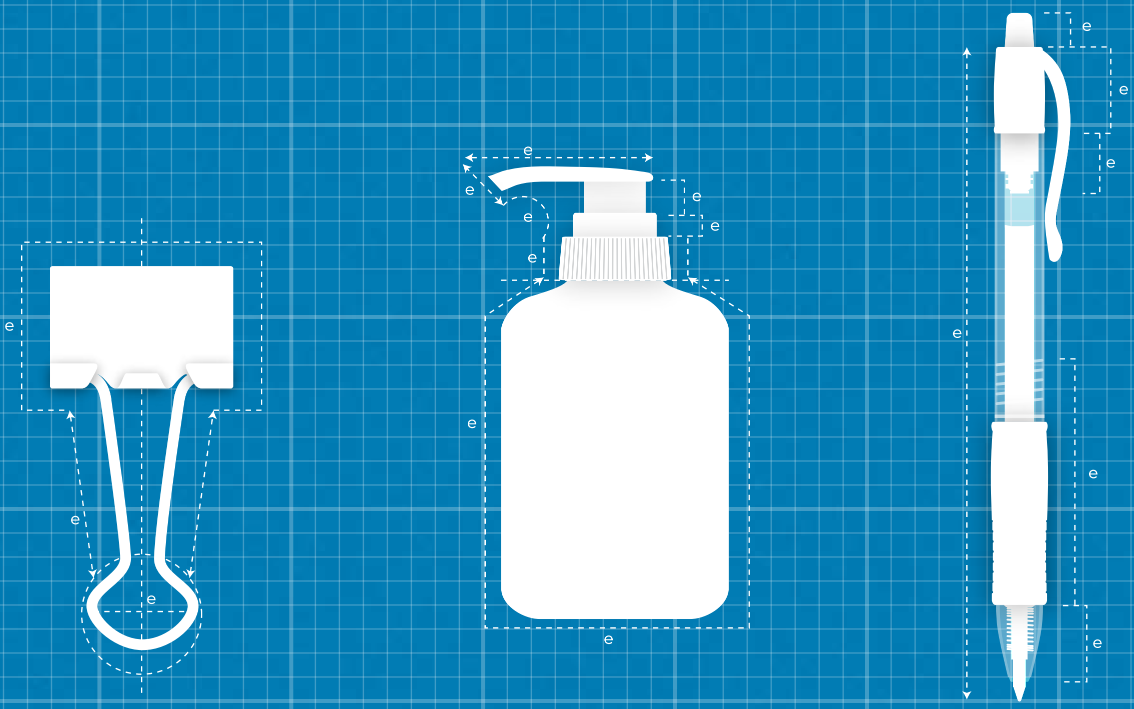
EVERYDAY ENGINEERING

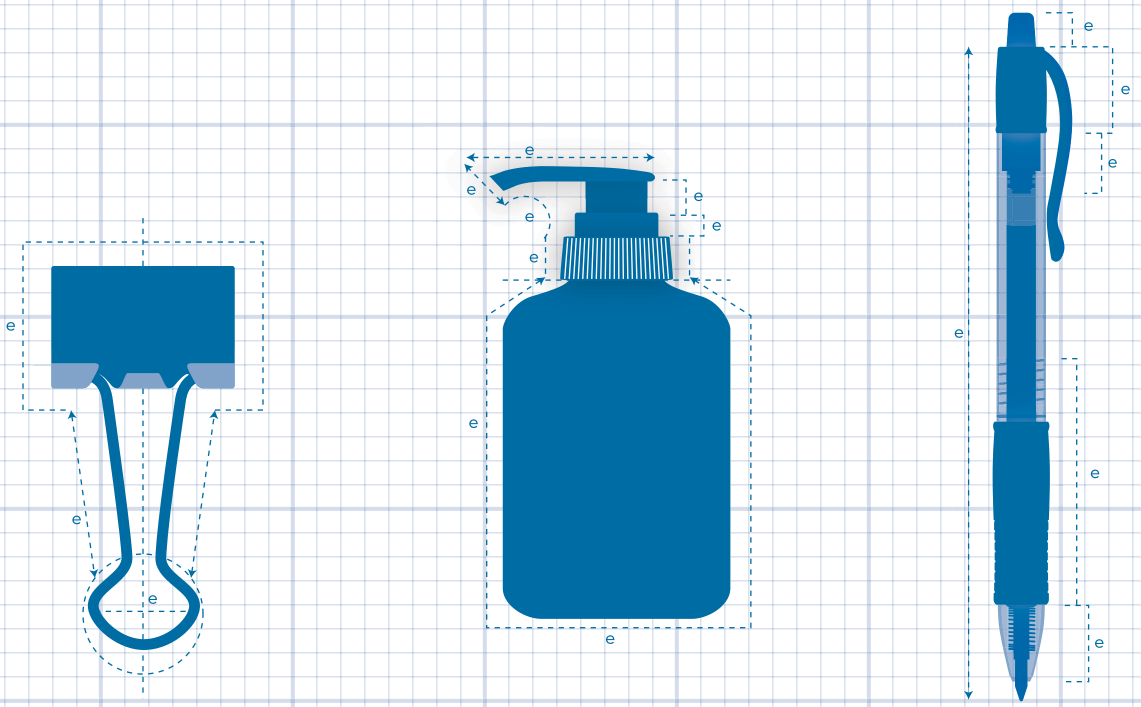


Putting the E in STEM Teaching and Learning

Richard H. Moyer and Susan A. Everett

NSTA press
National Science Teachers Association

EVERYDAY ENGINEERING



Putting the E in STEM Teaching and Learning

Everyday Engineering

Putting the E in STEM Teaching and Learning

Richard H. Moyer and Susan A. Everett

Photography by Robert L. Simpson III

NSTA press
National Science Teachers Association

Arlington, Virginia

NSTApress®
National Science Teachers Association

Claire Reinburg, Director
Jennifer Horak, Managing Editor
Andrew Cooke, Senior Editor
Wendy Rubin, Associate Editor
Agnes Bannigan, Associate Editor
Amy America, Book Acquisitions Coordinator

Art and Design
Will Thomas Jr., Director
Lucio Bracamontes, Graphic Designer, cover and interior design

Printing and Production
Catherine Lorrain, Director

National Science Teachers Association
Francis Q. Eberle, PhD, Executive Director
David Beacom, Publisher

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

15 14 13 12 4 3 2 1

NSTA is committed to publishing material that promotes the best in inquiry-based science education. However, conditions of actual use may vary, and the safety procedures and practices described in this book are intended to serve only as a guide. Additional precautionary measures may be required. NSTA and the authors do not warrant or represent that the procedures and practices in this book meet any safety code or standard of federal, state, or local regulations. NSTA and the authors disclaim any liability for personal injury or damage to property arising out of or relating to the use of this book, including any of the recommendations, instructions, or materials contained therein.

eISBN 978-1-936959-79-2

Library of Congress Cataloging-in-Publication Data
Moyer, Richard.
Everyday engineering : putting the E in STEM teaching and learning / Richard H. Moyer and Susan A. Everett ; photography by Robert L. Simpson III.
p. cm.
Articles previously published in Science scope.
Includes bibliographical references and index.
ISBN 978-1-936137-19-0
1. Inventions--Popular works. 2. Engineering--Popular works. I. Everett, Susan A. II. Title.
T47.M725 2012
620--dc23

2011050981

CONTENTS

PREFACE

THE IDEA FOR the "Everyday Engineering" column in *Science Scope* began with our interest in design and production issues related to the simple ballpoint pen. We were struck by the elegance of the means for retracting the reservoir and transferring the ink to paper. There are many engineering and science concepts involved in these processes. Almost all ballpoint pens work the same way. And some are sold for as little as 19 cents. This led to the development of an activity we used with our students and then a workshop at the Detroit NSTA Regional Conference in the fall of 2007. The pen material was published as "Everyday Engineering: What Makes a Bic Click?" (see Chapter 2) in the April/May 2009 issue of *Science Scope*. Another workshop was presented at a McGraw-Hill Science and Technology Symposium for science supervisors from across the country. The feedback from both teachers and administrators was overwhelmingly positive. We realized that others, too, shared our zeal for appreciating the engineering of simple, common, everyday devices.

For some months, we found ourselves taking a number of things apart—becoming more and more intrigued with the design of the seemingly simple. When thought about in this light, paper clips and pump soap dispensers become fascinating. Learning the history of how these everyday objects were developed is also fascinating. We then proposed to Inez Liftig, the editor of *Science Scope*, a regular feature called "Everyday Engineering" that would investigate the science and engineering of simple, everyday items. This proposal was quickly endorsed by Inez and the *Science Scope* Advisory Board. In order to provide teachers, scout leaders, workshop leaders, parents, and engineers leading outreach activities with the collection of "Everyday Engineering" ideas, this book was conceived.

We envision that *Everyday Engineering: Putting the* E *in STEM Teaching and Learning* can be used in a number of different ways. Since the new *A Framework for K–12 Science Education* (NRC 2011) includes engineering as a disciplinary core idea, teachers may use our book to integrate the engineering concepts within their normal science curriculum. Other teachers may wish to teach one or more separate engineering units. After-school group leaders, summer enrichment program administrators, and even youth group leaders may choose to use the activities as well. We also hope that parents who wish to share the world of engineering with their children will find this book to be beneficial since each activity is complete, includes safe procedures, and explains the science and engineering concepts involved as well as the history and development of the everyday object's design.

Richard H. Moyer and Susan A. Everett, October 2011, Dearborn, Michigan.

Reference

National Research Council (NRC). 2012. *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* Washington, DC: National Academies Press.

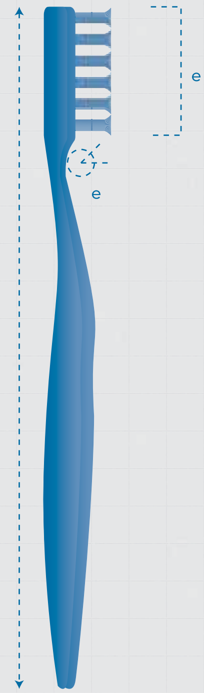
ACKNOWLEDGMENTS

THE AUTHORS ARE indebted to our students for their enthusiastic willingness to engage in the classroom activities we present. The feedback we receive is of great value. We are also appreciative of sixth-grade science teacher Cindy Pentland and her middle-level students in metropolitan Detroit. They were ready to try out our engineering activities on a regular basis and were always eager to get their hands on everyday devices and their minds involved in how things work. In addition, Samantha Hartshaw and Leah Walkuski, two of our student assistants, provided much help working through many of the activities in Ms. Pentland's classroom.

We also want to recognize our colleagues at the Inquiry Institute at the University of Michigan–Dearborn. Specifically, we want to thank Chris Burke, John Devlin, Charlotte Otto, Steve Rea, and Paul Zitzewitz for their willingness to talk with us about our ideas.

Finally, we are indebted to our editors at *Science Scope*: Editor Inez Liftig, Managing Editor Ken Roberts, and Consulting Editor Janna Palliser. Their good work makes us better. They work tirelessly to make *Science Scope* such an outstanding classroom aid to its thousands of readers. We are also grateful for the work done by Claire Reinburg, director of the NSTA Press and her outstanding staff, especially Agnes Bannigan, who was responsible for putting this volume together so seamlessly.

CHAPTER 9



TOOTHBRUSH DESIGN—IS THERE A BETTER BRISTLE?

WHAT KIND OF toothbrush do you use—manual or electric? What is the shape of the head and the handle? Could you describe the firmness and the layout of the bristles? Or count the number of bristles? With more than 3,000 toothbrush patents, is one type better than others for cleaning your teeth? Manufacturers often claim that their particular design is better than the competitors, but is it?

In this 5E Model lesson, students explore various manual toothbrush designs. One of ITEEA's standards urges students in grades 6 through 8 to learn that "there is no perfect design" (ITEA 2002, p. 95). As in the design of all products, engineers are faced with prioritizing costs and benefits. For example, a very simple toothbrush (see left-hand toothbrush in Figure 9.1, p. 64) can be purchased for 50 cents. A more complex toothbrush that has variable bristles intended to clean between different tooth surfaces and a bent handle to allow easy access to the hard-to-reach back of the mouth may cost \$3–\$5. Engineers must consider the economic issues as well as the functionality involved with selling the products they create: to produce the best possible toothbrush regardless of cost, the toothbrush that will sell the most, or perhaps the toothbrush that costs the least to produce.

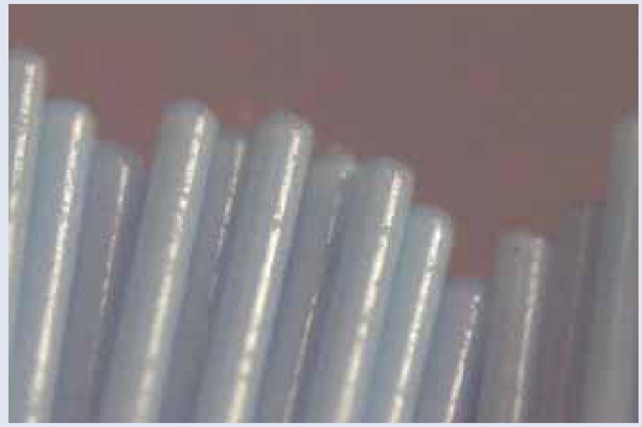
As with other lessons in this book, there is a connection to science content, as well. It is important for students to appreciate the value of proper dental hygiene. Regular effective brushing protects the body from dental caries (i.e., tooth decay and cavities) and periodontal disease, which may be associated with other health concerns, including heart health. You can use this lesson when focusing on the following National Science Education Standard: "Disease is a breakdown in structures or functions of an organism" (NRC 1996, p. 157).

Historical Information

Primitive toothbrushes have been found in tombs of ancient Egyptians, evidence that humans have been using devices to clean their teeth for at least 5,500 years. These first tooth "brushes" were usually made of twigs that had been frayed at one end to clean between teeth. In the 15th century, the Chinese used boar bristles stuck into a bone or a stick—sometimes made from aromatic trees—to brush their teeth, as well as to freshen the breath. Two hundred years later, Europeans were using rags soaked in salt solutions to clean their teeth. In 1780, William Addis made a toothbrush using hairs from a cow's tail attached to a handle carved from an ox's thighbone. The Addis family is still producing toothbrushes in England today. Toothbrush design did not change all that much until 1938, when nylon toothbrushes were introduced in the United States. Nylon proved to be beneficial because the bristles could

FIGURE 9.1 Toothbrush designs

FIGURE 9.2 Bristles at 30×



be shaped on the ends not only to be gentler but also to reach spaces between teeth and under the gum line (Figure 9.2). It also proved to be more hygienic, because the bristles were more resistant to bacteria growth than animal-hair bristles. It was not until after soldiers came home from World War II in 1945, however, that the idea of brushing one's teeth became popular with most Americans (ADA 2007).

During this activity, students may logically inquire about the purpose of toothpaste. You may want to have them research this on their own. Essentially, toothpaste serves a number of purposes. Most toothpastes contain a detergent to help clean the teeth. A flavor enhancer masks the taste of the detergent and freshens the breath. Most, but not all, toothpastes contain a fluoride compound to help prevent tooth decay. Children's toothpaste contains about a third less fluoride because they are more likely to swallow it. Toothpastes also usually contain some abrasive materials—a fine grit—to help scrub away plaque, and whiteners to remove superficial stains. Some people prefer natural toothpaste alternatives made of organic herbal material.

The earliest references to toothpastes date to 5000 BC in Egypt, where a paste was described for cleaning teeth. Over the years, toothpaste has evolved and has included various abrasives—some actually harmful to the enamel of the teeth. Before about 1850, tooth cleaners were actually powders and not pastes. The first toothpaste tube was introduced in 1890, and tube containers—another example of everyday engineering—are still used today (Colgate World of Care 2006).

Investigating Toothbrushes (Teacher Background Information)

Engage

Safety note: Remind students that marshmallow cream may not be eaten in the lab.

You will need to gather an assortment of toothbrushes of different designs. You might consider contacting local dentists for donations or purchasing some at your local dollar store. A less desirable option is to collect an assortment of used toothbrushes and then sterilize them by boiling or bleaching. For the Explore stage, each group of three to four students will need two different toothbrushes and two additional, more

FIGURE 9.3 Exploration setup

FIGURE 9.4 A more complex toothbrush

complex toothbrushes for the Extend phase. After rinsing, the toothbrushes can be reused for later classes. In addition, each group will need two plastic combs, two disposable cups, a cup of water to rinse brushes, a plastic knife, about 60 cm of electrical tape, and about 15 ml (1 tbsp.) of marshmallow cream (some groups may request additional cream for the second part of the Exploration). Also, students will need a few general supplies: some kind of tape (duct tape or electrical tape) to hold the materials to the lab table, scissors, and newspaper to protect the floor. Because students are planning their own experiments, they may request additional materials.

Even though we all use our toothbrushes (hopefully) at least twice a day, it is likely that most of us have never really studied this simple example of everyday engineering. Therefore, before distributing the toothbrushes, ask students what they know about toothbrushes and dental hygiene in general. You may wish to have students investigate some of the history of toothbrushes. Next, have students consider what their own toothbrushes look like and ask them to make a sketch. It is likely that students will have difficulty recalling specific details (e.g., whether the bristles are all the same height, the number of tufts in a row, the direction the tufts point, or the number of rows of tufts). After students share their drawings, distribute two different brushes to each group and ask students to compare them. Help students realize that toothbrushes have a range of features. In the second part of the exploration, students will test to discover if any of these differences result in a more effective toothbrush.

Explore

In this activity, students will set up two models of a mouth and teeth using a disposable cup and a plastic comb as shown in Figure 9.3. Students should place a piece of electrical tape around the base of the comb's teeth to represent the gum line and then evenly smear marshmallow cream on the teeth to simulate plaque and food particles. Each group of students should plan a fair test to determine whether or not one of their toothbrushes is more effective at cleaning the marshmallow cream off of the teeth of the combs.

One possible procedure might be to brush five strokes in one direction on each side of the comb, rinsing in between sides. To operationalize the dependent variable of effectiveness, students can visually compare

FIGURE 9.5 Toothbrush design features

Design feature	Purpose
Bent handle	Cleans hard-to-reach teeth in back of mouth
Thumb grip	Properly positions brush in hand to reach all parts of mouth
Flexible handle	Reduces pressure on gums
Soft rubber bristles along edge	Clean and massage along gum line
Bristles pointing in different directions	Clean spaces between teeth
Bristles of different lengths	Clean spaces between teeth
Rough area on back of brush	Scrubs the tongue and inside of the cheeks

the amount of marshmallow cream remaining on each comb. Students can also compare the amount remaining underneath the gum line.

In the second part of the exploration, students will determine how to get the model teeth as clean as possible. Here, the driving question is whether it is possible to clean the teeth regardless of which brush is used. Students will need to reapply the marshmallow cream and try out different brushing techniques. Students should make note of the techniques used.

Explain

Have students share their findings and compare differences and similarities. It is likely that students will be unable to see significant differences between their two toothbrushes if the techniques are carefully controlled. Students may be surprised that their results show little or no difference between expensive and inexpensive toothbrushes. Most of the toothbrushes used in this activity (especially if they came from dentists or major retail outlets) were probably approved by the American Dental Association (ADA). The ADA evaluates toothbrushes and gives the ADA Seal of Acceptance to those that meet their requirements. Currently, the approved list includes 34 different toothbrushes (ADA 2010); therefore, all should clean the teeth effectively. In fact, any toothbrush is likely to clean the model teeth similarly.

With sufficient brushing, students should be able to fully clean the model teeth with both of their brushes. Studies have shown that "there is no convincing evidence to support the idea that one type [of toothbrush] is better than the other in terms of its efficacy in plaque removal" (Sasan et al. 2006, p. 168). Students should conclude that the key factor is to brush for a sufficient amount of time and to reach all surfaces, including in between the teeth and along the gum line. To help answer additional questions, you may wish to ask a local dentist or hygienist to visit your class.

Extend

Provide two additional toothbrushes with more complex features (Figure 9.4, p. 65) to each group. These toothbrushes might have a curved or flexible handle,

FIGURE 9.6 Sample scoring rubric for toothbrush design activity

	3	2	1
Design	Creative design clearly meets some specific purpose.	Purpose and design are not well matched.	Purpose or design is not clearly stated.
Toothbrush information	Accurate information about toothbrush characteristics and functions is provided.	Some information about the toothbrush design is provided.	Inaccurate information about toothbrush characteristics and functions is provided.
Communication	Creatively and clearly communicates the selling points of the toothbrush.	Clear but not creative communication of the selling points is provided.	Communication of selling points is lacking or ineffective.

a thumb grip to properly position the brush in the hand, different types of bristles, and so on. Students should study the features of their brushes and make inferences as to their purpose. See Figure 9.5 for sample observations and inferences.

Evaluate

Because a perfect design does not exist, students should articulate some specific characteristics that a person may value in a toothbrush by creating an advertisement. For example, if a student values a very inexpensive toothbrush, the advertisement could indicate that people should take the time and effort to brush all tooth surfaces effectively. Students could either design a print advertisement or use a video camera to produce a video commercial. Students can make a drawing of their design rather than making the actual toothbrush itself. See Figure 9.6 for a sample scoring rubric.

Conclusion

The toothbrush analysis is a good example of the ITEEA standard that "there is no [one] perfect design" (ITEA 2002, p. 95). There are many equally effective toothbrushes from which to choose. As the ADA states, "Choose a toothbrush that you like and find easy to use so that you'll use it twice a day to thoroughly clean all of your tooth surfaces" (2007, p. 1288). Students should appreciate that in some cases a less complex engineering solution may be effective if properly used or applied. Toothbrush design is but one factor in effective oral hygiene, which is also impacted by brushing time, technique, and frequency.

References

American Dental Association (ADA). 2007. A look at toothbrushes. *Journal of American Dental Association* 138: 1288.

ADA. 2010. ADA Seal of Acceptance program and products. *www.ada.org/sealprogramproducts.aspx.*

Colgate World of Care. 2006. History of toothbrushes and toothpastes. *www.colgate.com/app/Colgate/US/OC/Information/OralHealthBasics/GoodOralHygiene/BrushingandFlossing/HistoryToothbrushesToothpastes.cvsp.*

International Technology Education Association (ITEA). 2002. *Standards for technological literacy: Content for the study of technology.* 2nd ed. Reston, VA: ITEA.

Moyer, R., J. Hackett, and S. Everett. 2007. T*eaching science as investigations: Modeling inquiry through learning cycle lessons*. Upper Saddle River, NJ: Pearson/Merrill/Prentice Hall.

National Research Council (NRC). 1996. *National science education standards.* Washington, DC: National Academies Press.

Sasan, D., B. Thomas, M. Bhat, K. S. Aithal, and P. R. Ramesh. 2006. Toothbrush selection: A dilemma? *Indian Journal of Dental Research* 17 (4): 167–70.

ACTIVITY WORKSHEET 9.1

Investigating Toothbrushes: Toothbrush Design—Does It Matter?

Engage

Safety note: Do not put toothbrushes or any of the lab materials in your mouth.

1. Make a drawing of what your toothbrush looks like. Try to remember how it is shaped and what the bristles look like.
2. Compare the two toothbrushes your teacher has provided. Note how they are similar and how they are different.
3. In this activity, you will design and conduct a test to determine if one of these brushes is more effective than the other. Write your prediction as well as your reasoning and discuss with your group.
4. Can you find a brushing technique that will allow you to clean teeth effectively with either brush?

Explore

Safety note: Marshmallow cream used to simulate plaque and food particles may not be eaten.

1. Discuss with your group a plan to conduct a fair test of the two toothbrushes using the model teeth and mouth your teacher has supplied.
2. In your plan be sure to include the following:
   a. A set procedure for brushing—number of strokes, pressure used, direction of brushing, rinsing of brush, and so on
   b. How you will determine the effectiveness of the toothbrushes
3. After your teacher has approved your plan, set up and conduct your test.
4. Record your findings.
5. Using the same materials, investigate what you have to do to get your model teeth as clean as possible. Compare different brushing techniques. Record your findings.

Explain

1. Share your group's findings with the rest of the class. How do your findings compare?
2. Was any one brush obviously more effective than others? What conclusion might you draw from this part of the investigation?
3. Discuss with the class the various methods used to get the model teeth as clean as possible. How well did each brush clean the model teeth?

Extend

1. Examine the different toothbrushes your teacher has provided.
2. Notice the variation in the design of each brush.
3. Thinking like an engineer, what do you think is the intended purpose for each design feature of each brush?

Toothbrush	Design feature	Purpose of feature
One		
Two		
Three		
Four		

4. Present your ideas to the rest of the class and discuss.

Evaluate

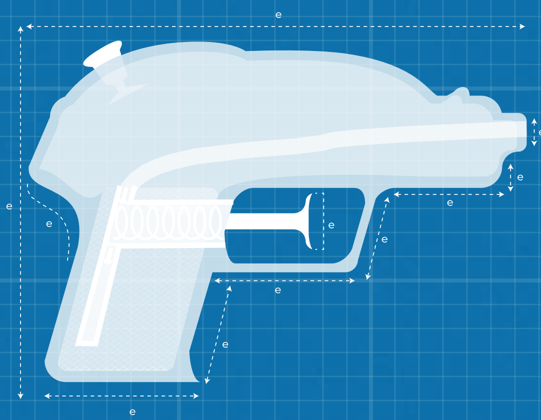
Review some advertisements for toothbrushes to see what different types exist. What are the advantages that the commercials stress as selling points? Create an advertisement for a new toothbrush noting the purpose and advantages of your design.

INDEX

Page numbers printed in ***boldface*** *type refer to figures.*

EVERYDAY ENGINEERING

Putting the E in STEM Teaching and Learning



"The idea for ***Everyday Engineering*** began with our interest in design and production issues related to the simple ballpoint pen. We were struck by the elegance of the means for retracting the reservoir and transferring the ink to paper. ... For some months, we found ourselves taking a number of things apart—becoming more and more intrigued with the design of the seemingly simple. When thought about in this light, paper clips and pump soap dispensers become fascinating. Learning the history of how these everyday objects were developed is also fascinating." —From the introduction to *Everyday Engineering*

Here's an ideal way to spark students' fascination with the marvels of engineering behind the seemingly simple. This book is a compilation of popular "Everyday Engineering" columns from NSTA's middle school journal, *Science Scope*. The collection is made up of 14 activities that explore engineering's role in five areas: the office, the kitchen, the bathroom, electricity, and outdoor recreation. Students can perform hands-on investigations of objects they use all the time, asking questions such as

- What makes a Bic click?
- Why do squirt guns squirt?
- What makes a better cereal box?

Each activity includes a clear explanation of the science and history behind the object's development plus a materials list, student data sheets, and safety suggestions. The collection is useful to classroom teachers as well as scout leaders, engineers leading outreach activities, after-school and summer enrichment program staff, and parents.

Everyday Engineering may soon have your students taking a number of things apart—and putting together a lifelong interest in engineering.

Grades 6–8

NSTA press
National Science Teachers Association

PB306X
ISBN: 978-1-936137-19-0