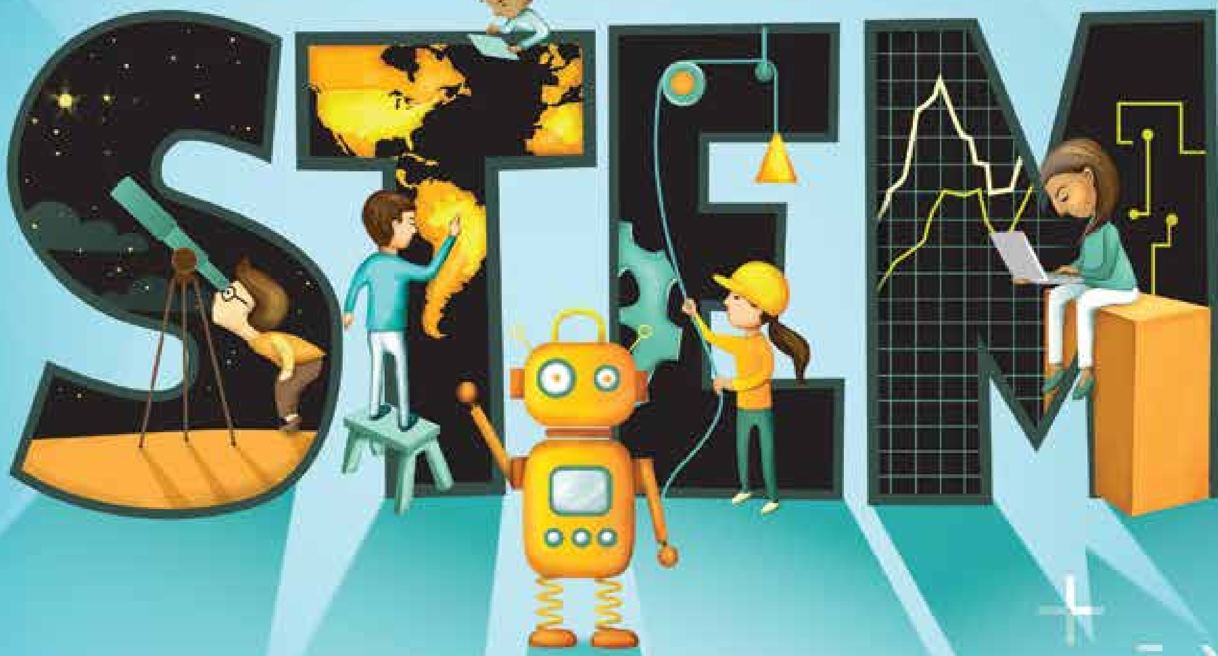
Picture-Perfect STEM Lessons, 3–5

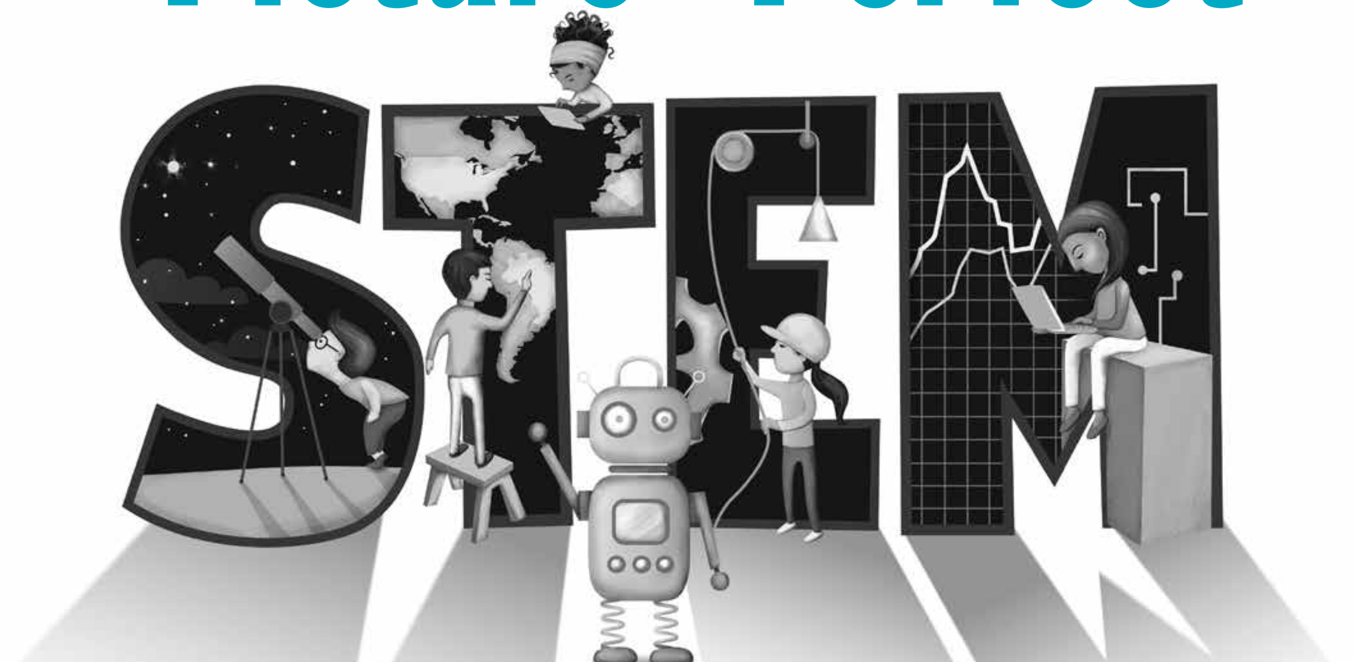


Using Children's Books to Inspire STEM Learning

by Emily Morgan and Karen Ansberry

NSTA press
National Science Teachers Association

Picture-Perfect



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NSTApress
National Science Teachers Association
Arlington, Virginia

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Contents

Preface

Third-grade students listen as their teacher reads *Clink,* the humorous and heartwarming story of a lovable, worn-out, music-playing, toast-making house robot who sits discarded in the Robot Shoppe. Clink nearly gives up on finding a home—until the day he spies a boy who just might have the right one for him …

> *The shopkeeper handed Clink to the boy. "He's very old, and he's missing parts."*
>
> *The boy's eyes lit up. "He's perfect!"*
>
> *"I'm perfect?" thought Clink. It had been a very long time since anybody had thought he was perfect. Clink smiled. PLINK! POP!*
>
> *The boy ducked. "I'll take him!" he said.*

The third graders delight in this heartfelt tale of yearning to belong and to be accepted for who you are. It not only engages students on an emotional level but also provides a unique transition to a discussion of toys—how they work and how they are designed. After the read-aloud, the class explores wind-up toy robots. Students observe their robots' patterns of motion, graph the distance they travel, and predict their future motion. Then, they take the toys apart to see how they work. Through a nonfiction read-aloud they learn about the technology required to design and manufacture springs and how springs inside wind-up toys store energy that is released when the spring unwinds. Students discover that a surprising amount of science and engineering is packed inside a small wind-up toy! Next, students build their own wind-up spool cars and modify, test, and evaluate their designs. This activity addresses the engineering core idea that different solutions need to be tested to determine which solution best solves the problem, given the criteria and constraints. Students apply what they have learned by writing an instruction manual that explains how the wind-up car works, demonstrating their understanding of the physical science core idea of forces and motion. Finally, they reflect on what they have learned through a STEM at Home assignment. With a parent or adult helper, they watch a video called *Scientist Profile: Toyologist,* which is about an engineer who designs toys. Then, they draw a patent illustration for a wind-up toy of their own design. Through this engaging, hands-on lesson found in Chapter 8, "Wind It Up," students learn about the interdependence of science, technology, engineering, and mathematics in the toy-making industry—all within the context of a delightful, fictional story.

What Is Picture-Perfect STEM?

The Picture-Perfect Science program was developed to help K–5 teachers integrate science and reading in an engaging, kid-friendly way. Since the debut of the first book in the *Picture-Perfect Science Lessons* series in 2005, elementary teachers across the country have been using the lessons to integrate science and literacy. This new series of Picture-Perfect books, *Picture-Perfect STEM Lessons: Using Children's Books to Inspire STEM Learning*, follows the same philosophy and lesson format as the original books but adds an additional emphasis on the intersection of science, technology, engineering, and mathematics in the real world. *Picture-Perfect STEM Lessons, 3–5* contains 15 lessons for students in grade three through grade five, with embedded reading comprehension strategies to help them learn to read and read to learn while engaged in STEM activities. To help you set up a learning environment consistent with the principles of *A Framework for K–12 Science Education* (*Framework;* NRC 2012), the lessons are written in an easy-to-follow format of constructivist learning—the Biological Science Curriculum Study (BSCS) 5E Instructional Model (Bybee 1997, used with permission from BSCS; see Chapter 3 for more information). This learning cycle model allows students to construct their own understanding of scientific concepts as they cycle through the following phases: engage, explore, explain, elaborate, and evaluate. Although *Picture-Perfect STEM Lessons* is primarily a book for teaching STEM concepts, reading comprehension strategies and the *Common Core State Standards for English Language Arts* (NGAC and CCSSO 2010) are embedded in each lesson. These essential strategies can be modeled while keeping the focus of the lessons on STEM.

Use This Book Within Your Curriculum

We wrote *Picture-Perfect STEM Lessons* to supplement, not replace, your school's existing science or STEM program. Although each lesson stands alone as a carefully planned learning cycle based on clearly defined objectives, the lessons are intended to be integrated into a complete curriculum in which concepts can be more fully developed. The lessons are not designed to be taught sequentially. We want you to use *Picture-Perfect STEM Lessons* where appropriate within your school's current STEM program to support, enrich, and extend it. We also want you to adapt the lessons to fit your school's curriculum, your students' needs, and your own teaching style.

Special Features of This Book

Ready-to-Use Lessons With Assessments

Each lesson contains engagement activities, hands-on explorations, student pages, suggestions for student and teacher explanations, elaboration activities, assessment suggestions, opportunities for STEM education at home, and annotated bibliographies of more books to read on the topic. Assessments include poster sessions, writing assignments, design challenges, demonstrations, presentations, and multiple-choice and extended-response questions.

Background for Teachers

This section provides easy-to-understand background information for teachers to review before facilitating the lesson. Some information in the background section goes beyond the assessment boundary for students, but it is provided to give teachers a deeper understanding of the content presented in the lesson.

Time Needed

The information in this section helps you pace each lesson. We estimate a primary class period to be about 30–45 min.

Reading-Comprehension Strategies

Reading-comprehension strategies based on the book *Strategies That Work* (Harvey and Goudvis 2007) and specific activities to enhance comprehension are embedded throughout the lessons and clearly marked with an icon. Chapter 2 describes how to model these strategies while reading aloud to students.

Standards-Based Objectives

All lesson objectives are aligned to the *Framework* (NRC 2012) and are clearly identified at the beginning of each lesson. An alignment with the *Next Generation Science Standards* (NGSS Lead States 2013) is included in the appendix (p. 365). The lessons also incorporate the *Common Core State Standards for English Language Arts and Mathematics* (NGAC and CCSSO 2010). In a box titled "Connecting to the Common Core," you will find the Common Core subject the activity addresses as well as the grade level and standard number. You will see that writing assignments are specifically labeled with an icon: .

STEM at Home

Each lesson also provides an extension activity that is intended to be done with a parent or other adult helper at home. Students write about what they learned about each topic and share their favorite part of the lesson. Then, together with their adult helper, they complete an activity to apply and extend the learning. If students are unable to complete the extension at home, the activities in this section also work well as in-class extensions.

Ideas for Further Exploration

A "For Further Exploration" box is provided at the end of each lesson to help you encourage your students to use the science and engineering practices in a more student-directed format. This box lists questions and challenges related to the lesson that students may select to research, investigate, or innovate. Students may also use the questions as examples to help them generate their own questions. After selecting one of the questions in the box or formulating their own questions, students can make predictions, design investigations to test their predictions, collect evidence, devise explanations, design solutions, examine related resources, and communicate their findings.

References

Bybee, R. W. 1997. *Achieving scientific literacy: From purposes to practices.* Portsmouth, NH: Heinemann.

Harvey, S., and A. Goudvis. 2007. *Strategies that work: Teaching comprehension for understanding and engagement.* 2nd ed. Portland, ME: Stenhouse Publishers.

National Governors Association Center for Best Practices and Council of Chief State School Officers (NGAC and CCSSO). 2010. *Common core state standards.* Washington, DC: NGAC and CCSSO.

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

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press. *www.nextgenscience.org/next-generation-science-standards.*

Children's Book Cited

DiPucchio, K. 2011. *Clink.* New York: Balzer + Bray.

Editor's Note

Picture-Perfect STEM Lessons, 3–5 builds on the texts of 30 children's picture books to teach STEM. Some of these books feature objects that have been anthropomorphized, such as a robot who longs for a friend. Although we recognize that many scientists and educators believe that personification, teleology, animism, and anthropomorphism promote misconceptions among young children, others believe that removing these elements would leave children's literature severely underpopulated. Furthermore, backers of these techniques not only see little harm in their use but also argue that they facilitate learning. Because *Picture-Perfect STEM Lessons, 3–5* specifically and carefully supports science and engineering practices, we, like our authors, feel the question remains open.

Acknowledgments

We would like to dedicate this book to the memory of Dr. Robert Yearout, who gave us the opportunity to present our first teacher workshop at the "Sharing What Works" Conference in Columbus, Ohio, in 2000. Dr. Yearout's leadership of the High Achievement in Math and Science Consortium, which we were both fortunate to be a part of for many years, provided us with opportunities and encouragement to grow as educators and advocates of science and math education. His selfless leadership style and utmost respect for the teaching profession continue to inspire us today.

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About the Authors

Emily Morgan is a former elementary science lab teacher for Mason City Schools in Mason, Ohio, and seventh-grade science teacher at Northridge Local Schools in Dayton, Ohio. She served as a science consultant for the Hamilton County Educational Service Center and science leader for the High AIMS Consortium. She has a bachelor of science in elementary education from Wright State University and a master of science in education from the University of Dayton. She is also the author of the *Next Time You See* picture book series from NSTA Press. Emily lives in West Chester, Ohio, with her husband, son, and an assortment of animals.

Karen Ansberry is a former elementary science curriculum leader and fifth- and sixth-grade teacher at Mason City Schools in Mason, Ohio. She has a bachelor of science in biology from Xavier University and a master of arts in teaching from Miami University. Karen lives in historic Lebanon, Ohio, with her husband, two sons, two daughters, and two dogs.

Emily and Karen enjoy facilitating teacher workshops at elementary schools, universities, and professional conferences across the country. This is Emily and Karen's fourth book in the *Picture-Perfect Science Lessons* series. For more information on this series and teacher workshops, visit *www.pictureperfectscience.com.*

Safety Practices for Science Activities

With hands-on, process- and inquiry-based science activities, the teaching and learning of science today can be both effective and exciting. The challenge to securing this success needs to be met by addressing potential safety issues relative to engineering controls (ventilation, eye wash station, etc.), administrative procedures and safety operating procedures, and use of appropriate personal protective equipment (indirectly vented chemicals splash goggles meeting ANSI Z87.1 standard, chemical resistant aprons and gloves, etc.). Teachers can make it safer for students and themselves by adopting, implementing, and enforcing legal safety standards and better professional safety practices in the science classroom and laboratory. Throughout this book, safety notes are provided for science activities and need to be adopted and enforced in efforts to provide for a safer learning and teaching experience. Teachers should also review and follow local policies and protocols used in their school district and/or school (e.g., employer OSHA Hazard Communication Safety Plan and Board of Education safety policies).

Additional applicable standard operating procedures can be found in the National Science Teacher Association's "Safety in the Science Classroom, Laboratory, or Field Sites" (*www.nsta.org/docs/SafetyInTheScienceClassroomLabAndField.pdf*). Students should be required to review the document or one similar to it for elementary-level students under the direction of the teacher. It is important to also include safety information about working at home for the "STEM at Home" activities. Both the student and the parent or guardian should then sign the document acknowledging procedures that must be followed for a safer working and learning experience in the classroom, laboratory, or field. The Council of State Science Supervisors also has a safety resource for elementary science activities titled "Science and Safety: It's Elementary!" Teachers can consult this document at *www.csss-science.org/downloads/scisaf_cal.pdf*.

Please note that the safety precautions of each activity are based, in part, on use of the recommended materials and instructions, legal safety standards, and better professional practices. Selection of alternative materials or procedures for these activities may jeopardize the level of safety and therefore is at the user's own risk.

The Inventor's Secret

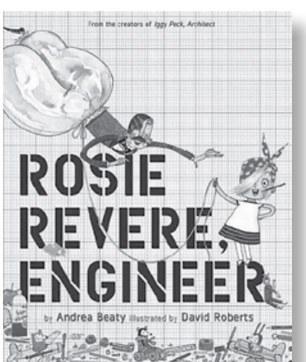
Description

Two books that emphasize the power of perseverance are paired, engaging students in a challenge to design a toy car using everyday materials. Students are introduced to the design process and use it to improve their car design.

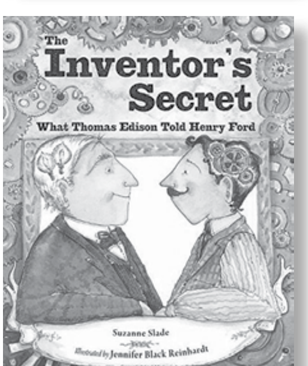
Suggested Grade Levels: 3–5

LESSON OBJECTIVES Connecting to the *Framework*		
Science and Engineering Practices	**Disciplinary Core Ideas**	**Crosscutting Concept**
Planning and Carrying Out Investigations Constructing Explanations and Designing Solutions	**ETS1.C:** Optimizing the Design Solution **ETS2.B:** Influence of Engineering, Technology, and Science on Society and the Natural World	Structure and Function

Featured Picture Books



TITLE: ***Rosie Revere, Engineer***
AUTHOR: **Andrea Beaty**
ILLUSTRATOR: **David Roberts**
PUBLISHER: **Abrams Books for Young Readers**
YEAR: **2013**
GENRE: **Story**
SUMMARY: *Young Rosie dreams of being an engineer. Alone in her room at night, she constructs great inventions from odds and ends. Afraid of failure, Rosie hides her creations under her bed until a fateful visit from her great-great-aunt Rose, who shows her that a first flop isn't something to fear—it's something to celebrate.*



TITLE: ***The Inventor's Secret: What Thomas Edison Told Henry Ford***
AUTHOR: **Suzanne Slade**
ILLUSTRATOR: **Jennifer Black Reinhardt**
PUBLISHER: **Charlesbridge**
YEAR: **2015**
GENRE: **Narrative Information**
SUMMARY: *This delightful book about Henry Ford's quest to make an affordable car also portrays the friendship between him and Thomas Edison, including the fateful moment when Ford learned Edison's secret to inventing—keep at it!*

Time Needed

This lesson will take several class periods. Suggested scheduling is as follows:

Day 1: **Engage** with *Rosie Revere, Engineer* Read-Aloud and **Explore** with Balloon Car Challenge, Part 1, and PBS *Design Squad Global* Video

Day 2: **Explore** with Balloon Car Challenge, Part 2

Day 3: **Explain** with *The Inventor's Secret* Read-Aloud and The Design Process and **Elaborate** with Edison Quotes

Day 4: **Evaluate** with Balloon Car Challenge, Part 3

Materials

For Build and Test a Balloon Car (per class)

You will need a variety of materials that can be used for different parts of the balloon cars. Organize the materials into five bins labeled *power source, body, wheels, axles,* and *materials for attaching*. The materials needed for each bin are as follows:

- Power source
  - Straws
  - Balloons, all the same size
  - Tape
  - Rubber bands
- Body
  - Empty water bottle
  - Clean, empty juice box or other small box
  - Disposable cup
  - Cardboard
- Wheels
  - Plastic bottle caps
  - Candy mints (with hole in the middle)
  - CDs
  - Cardboard
- Axles
  - Straws
  - Wooden skewers
  - Chopsticks
  - Cotton swabs
- Materials for attaching
  - Tape
  - Foam

SAFETY

- Before using balloons in the classroom, be sure that no one is allergic to latex.
- Have students wear safety glasses or goggles during this activity.
- Remind students not to eat any food used in this activity.
- Wash hands with soap and water after completing this activity.

- Modeling clay
- Glue
- Pieces of dry sponge

For Build and Test a Balloon Car (per group of 3–4 students)

- Air pump for blowing up balloons
- Metersticks or tape measures

Additional class materials

- The Design Process poster (enlarged version of p. 74; full-color version available on the Extras page at *www.nsta.org/PicturePerfectSTEM3-5*)
- Edison Quotes (1 set cut into strips)

Student Pages

- Balloon Car Design Challenge
- Redesign, Build, Test & Evaluate
- Prototype Display Card
- STEM at Home

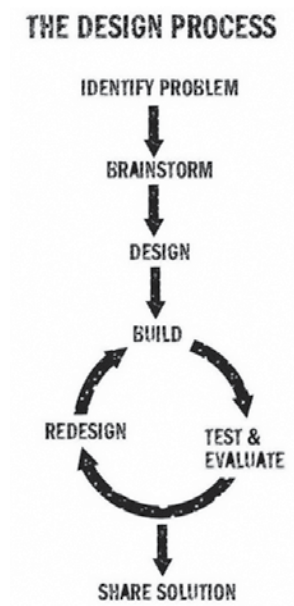
Background for Teachers

Thomas Edison and Henry Ford are two of the most famous inventors in history. Edison's inventions are too numerous to list here (2,332 patents worldwide), but many of them have changed the way we live. His most famous inventions were the phonograph, kinetoscope, dictaphone, and, of course, the incandescent light bulb. Although Ford did not invent the automobile, he is credited with developing the first car that most working people could afford, the Model T. His introduction of the Model T revolutionized transportation, and the moving assembly line he designed to manufacture the Model T transformed American industry.

Edison was Ford's hero. Sixteen years Edison's junior, a young and ambitious Henry Ford admired Edison's imagination and seemingly limitless talent for inventing new technologies. As Ford struggled with designing an affordable, gas-powered car, Edison was inventing at an incredible pace. In 1896, Ford had the chance to meet Edison at a convention in New York. After seeing Ford's designs, Edison banged his fist on the table and told Ford to "Keep at it!" Ford later said of the fortuitous meeting, "That bang on the table was worth worlds to me! No man up to then had given me any encouragement … and out of the clear blue sky the greatest inventive genius of the world had given me a complete approval." (p. 40 of *The Inventor's Secret*) Ford went on to experience great success with his Model T and Ford Motor Company.

Edison and Ford eventually became good friends. They even went on camping trips together and discussed their ideas. Ford eventually built a house right next door to Edison's winter home in Fort Meyers, Florida. The two friends installed a gate between the two houses so that they could visit each other. The gate was later nicknamed the *friendship gate.*

The story of *The Inventor's Secret* is used to engage students in a design challenge that supports the "Keep at it!" theme as they build toy cars out of everyday materials. This lesson features a version of the design process used by inventors and engineers. Several versions of this process exist, but they all have the same basic components. The version used by the PBS Kids television show *Design Squad Global* emphasizes the iterative component of the design process: to keep building, testing, evaluating, and redesigning until you are satisfied with the solution (in other words, "Keep at it!"). See the "Websites" section for more information about *Design Squad Global.* Both of the picture books featured in this lesson highlight the Build, Test & Evaluate, Redesign Cycle in this model.



Source: PBS 2016.

A Framework for K–12 Science Education represents the cycle in ETS1.C: Optimizing the Design Solution (NRC 2012). This engineering design disciplinary core idea states that, by the end of grade 5, students should understand that "different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints" (NRC 2012, p. 209). The lesson in this chapter also addresses the practices of planning and carrying out investigations and constructing explanations and designing solutions, as well as the crosscutting concept of structure and function.

Note: The balloon car design challenge introduced in the explore phase of this lesson was chosen because Henry Ford designed automobiles. However, this lesson could be used to frame other design challenges.

engage

Rosie Revere, Engineer Read-Aloud

Connecting to the Common Core
Reading: Literature
Key Ideas and Details: 3.3, 4.3

Questioning

Show students the cover of *Rosie Revere, Engineer.* Introduce the author, Andrea Beaty, and the illustrator, David Roberts. Students may recognize this author–illustrator team from the book *Iggy Peck, Architect* or *Ada Twist, Scientist.* Open the book so students can see the picture on the front and back covers. *Ask*

? What do you think this book is about?

As you read, stop periodically to ask the following questions:

? Page 7—Why do you think Rosie hides her inventions? (Answers will vary.)

? Page 13—Why *did* she hide her inventions? (She was laughed at when they didn't work. She was embarrassed.)

? Page 32 (show the illustration of the flying cheese-copter on the copyright page)—Was Rosie's invention ultimately a success? (yes) Why? (It flew!)

After reading, *ask*

? What happened that encouraged Rosie to not be ashamed of her invention attempts? (Her great-great-aunt Rose visited her and told her that it was the perfect first try.)

? How is Rosie an engineer? (Students should recognize that Rosie takes things apart, builds things to solve problems, and tests her inventions. All of these are things that engineers do.)

? What would you say is the moral of the story? (Never give up. True failure comes only if you quit.)

Connecting to the Common Core
Reading: Literature
Key Ideas and Details: 3.2, 4.2, 5.2

After reading, students may be interested in viewing a 6 min. video that features the author of the book discussing what inspired her to write the book and how science and art are related (see "Websites" section).

Next, open the book to pages 6–7, which show Rosie's attic. *Ask*

? Where does Rosie get all of the materials she uses to create new gadgets and gizmos? (They should recognize from the illustrations that Rosie gets her parts from machines, appliances, and discarded toys.)

explore

Balloon Car Challenge, Part 1: Identify Problem, Brainstorm, and Design

Tell students that, as did Rosie, they are going to make a vehicle out of some everyday materials. Give students the Balloon Car Design Challenge student page and present the problem, or design challenge, to students.

Identify Problem

Explain that inventors and engineers always have desired features or outcomes in mind when designing solutions to problems or design challenges, whether those solutions are projects, products, systems, or technologies. These desired features and outcomes are known as *criteria.* The criteria for this design challenge are as follows:

- Must be powered by a balloon
- Must travel in a straight line
- Must travel at least 30 cm on one full balloon of air

Explain that inventors and engineers also have to work within constraints when designing solutions. *Constraints* are typically limits on time, materials, and money. The constraints for the Balloon Car Design Challenge are as follows:

- Materials: You may use only materials provided by or approved by your teacher.
- Time: You must build your balloon car within the time limit set by your teacher.

Brainstorm

Show students the materials they can use. Have them brainstorm how they could assemble the materials to make a car. Be sure to explain that there is no perfect design or one "right" way of making the car. Different solutions can be made to solve the same problem. The best designs meet the criteria within the given constraints. Stimulate creative thinking by asking questions such as the following:

? What are the choices to use for the axles?

? What do you think would work best for the wheels?

? How could you attach the wheels to the axles?

? What could you use to make the body of the car?

? How could you attach the balloon to the car?

PBS *Design Squad Global* Video

After students have brainstormed several ideas, show them the "4-Wheel Balloon Car" video from the PBS Show *Design Squad Global* for more ideas (see "Websites" section). This website also features step-by-step instructions for making the cars.

Design

Have students sketch their balloon car idea. Next, have them write how they will test their car to see if it meets the criteria. When students have completed the student page, sign off at the teacher checkpoint. Tell students that they will be able to build and test their car during the next class period.

Building a Balloon Car

Balloon Car Challenge, Part 2: Build and Test & Evaluate

Remind students of the criteria and constraints defined in the challenge. Show them where to find their supplies. Set a realistic time limit appropriate for the age of your students. Tell students that they may test their cars during that time, but they will need to stop as soon as they hear the timer or hear you say, "Stop!" Give students updates on the time they have remaining as they build and test. When time is up, have students stop and put their cars aside. Tell them that they will have a chance to revise their original designs during another class period. Then, *ask*

- ? Did your car meet the criteria (powered by a balloon, travels in a straight line, and moves at least 30 cm on one full balloon of air)?
- ? Did you stay within the constraints of the challenge (built with approved materials and built within the time limit)?
- ? What is something that didn't work?
- ? What is something that worked well?
- ? What ideas do you have for improving your car?
- ? Did you ever feel like giving up?
- ? What would you say is the "secret" to inventing or engineering?

explain

The Inventor's Secret Read-Aloud

Questioning

Tell students that you have a book that might help them with their car design process. Show students the cover of *The Inventor's Secret,* and introduce the author and illustrator. Share the subtitle, *What Thomas Edison Told Henry Ford,* and *ask*

- ? Who was Thomas Edison? (Answers will vary, but students will likely know Edison invented the light bulb.)
- ? Who was Henry Ford? (Answers will vary, but students will likely associate Ford with cars.)
- ? Did Thomas Edison and Henry Ford know each other? (Answers will vary.)
- ? What do you think the "inventor's secret" might be? (Answers will vary.)

> Connecting to the Common Core
> **Reading: Informational Text**
> Key Ideas and Details: 3.1, 4.1, 5.1

Determining Importance

Tell students that, as you read, you would like them to listen for the "inventor's secret" and signal (raise their hands) when they hear it.

Questioning

Read the book aloud, stopping to ask the following questions (you may want to write the questions on sticky notes and place them within the book as reminders for you before reading):

- ? Page 8—Who was older, Thomas Edison or Henry Ford? (Edison) By how much? (16 years)
- ? Page 9—What did young Thomas and young Henry have in common? (They both wondered how things work, they built things, and sometimes they got into trouble for building things.)
- ? Page 24—What criteria (desired features or outcomes) did Henry Ford want his car to meet? (To run on gas, to be easy to drive, to be big enough for families, and to be affordable)
- ? Page 25—How do you think Henry Ford was feeling at this point in the story? (discouraged, jealous, frustrated) What makes you think that? (The book says he "couldn't stand it any longer," and he looks discouraged in the illustrations.)
- ? Page 29—Why do you think Thomas Edison banged his fist on the table? (to emphasize his point that Ford should "Keep at it!")
- ? Page 37—Why did Henry Ford have so many different Models—Model A, Model C, Model F, Model K, and so on? (Each one failed to meet Henry Ford's criteria for success, so he kept improving on them. He used the alphabet for the order of his revised prototypes.)
- ? Page 37—Which model was the one that finally met the criteria? (the Model T)
- ? Page 39—So what is the inventor's secret? ("Keep at it!")

Tell students that this story is based on true events. Read the quote from Henry Ford on page 40:

> *"That bang on the table was worth worlds to me! No man up to then had given me any encouragement…and out of a clear sky the greatest inventive genius in the world have given me complete approval."—Henry Ford after meeting Thomas Edison*

Ask

- ? Why do you think that moment was so important to Henry Ford? (He was feeling discouraged and needed encouragement to carry on his work. Thomas Edison was someone he admired.)

Read the information on pages 40–41 about Edison and Ford's friendship, and read the author's and illustrator's notes, which give the reader insight on their purpose and background.

The Design Process

Explain to students that inventors and engineers (like Thomas Edison and Henry Ford) use the Design Process when approaching a problem. There are several versions of the design process, but they all have the same basic ideas. Make a poster-sized version of The Design Process (see p. 74), which features the model used on the PBS show *Design Squad Global*. Using the poster and Table 6.1 (p. 68) as a guide, discuss each step of the process and what it means. Then, ask students to find evidence in the text that shows how Ford used each step of the design process while working on his car. Refer to the book when giving examples (page numbers are listed).

Ask

- ? What part of the design process do you think was highlighted in this book? (the Build, Test & Evaluate, Redesign Cycle)
- ? What evidence in the text makes you think so? (The author spends a lot of time writing about Ford's different attempts, tests, and redesigns.)

Explain that the Build, Test & Evaluate, Redesign Cycle can go on and on for a long time. *Ask*

- ? How long after Edison and Ford's meeting (depicted in the book) do you think it was before Ford introduced the Model T? (Students can use the time line in the back of the book to find the dates of these two events. The meeting

Table 6.1. Design Process Discussion Guide

Step	What It Means	How Henry Ford Used It

Identify a Problem	Find a problem to solve and identify the criteria for success.	• (p. 14) Ford's problem was to invent a new kind of vehicle that did not need a horse to pull it.
		• (p. 24) Ford identified the following criteria for success for his car:
		  • Runs on gas
		  • Easy to drive
		  • Big enough for families
		  • Affordable

Brainstorm	Come up with lots of ideas that might work.	• (pp.18–23) Ford had many ideas—using a steam engine, hooking up a homemade engine to a mower, using a two-cylinder gas engine, and using a four-cylinder gas engine.
Design	Make drawings, sketches, or plans for creating the solution.	• (p. 28) Ford shared a sketch of his four-cylinder engine with Edison. • (pp. 38–39) Some of Ford's and Edison's sketches for patents are shown.
Build, Test & Evaluate, Redesign	Build the solution, see if it works, make changes, test it again, and so on. This step is a cycle that can continue until the solution meets the criteria.	• (pp. 22–37) Throughout the book, Ford was building vehicles, testing them, evaluating them based on his criteria, redesigning, building again, testing, and so on.
Share Solution	Tell others about your solution.	Ford introduced the Model T (Tin Lizzie) to the world in 1908 and eventually sold millions of them.

was in 1896, and the Model T was released in 1908. That is 12 years!)

? In those 12 years, do you think Henry Ford had moments when he felt like giving up? (yes)

Making Connections: Text to Text

? Think back to *Rosie Revere, Engineer.* Where was the Build, Test & Evaluate, Redesign Cycle evident in the story? (She built the cheese-copter, she tested it, it crashed, she thought it was a failure, she worked the rest of the day redesigning it, and finally it flew.)

? Do you think other inventors and engineers ever feel like giving up? (yes)

elaborate

Edison Quotes

Many would consider Edison the greatest inventor (or engineer) of all time. His words inspired Ford not to give up, and his words have also encouraged many others as well. People all over the world have long been inspired by Edison's ingenuity, work ethic, appreciation of his team, and, of course, perseverance.

Form student groups of three or four and give each group a strip of paper with one of the following quotes from Edison:

- *Genius is 1% inspiration and 99% perspiration.*
- *I have not failed. I have just found 10,000 ways that do not work.*
- *Our greatest weakness lies in giving up. The most certain way to succeed is to try just one more time.*
- *Just because something doesn't do what you planned it to do, doesn't mean it's useless.*
- *I never did a day's work in my life. It was all fun.*
- *I have friends in overalls that I would not swap for the favor of the kings of the world.*
- *To invent, you need a good imagination and a pile of junk.*
- *If we did all the things we were capable of, we would literally astound ourselves.*

Ask each group to read their quote, look up any words they don't know, discuss the meaning with their group members, and consider what the quote tells us about Edison as a person and an inventor. Then, have each group share their Edison quote and interpretation with the rest of the class. After everyone is done sharing, *ask*

? What do these quotes tell us about Thomas Edison? (He didn't give up, he did not let failure make him quit, he loved the work he did, he valued his team, etc.)

? What does your group's quote tell you about being an inventor or engineer? (Answers will vary.)

Making Connections: Text to Text

> Connecting to the Common Core
> **Reading: Informational Text**
> Integration of Knowledge and Ideas: 3.9, 4.9, 5.9

Next, *ask*

? What do the two books we read in this lesson, *Rosie Revere, Engineer* and *The Inventor's Secret*, have in common? (They both have the same message: Don't give up.)

? How are the two books different? (*Rosie Revere, Engineer* is fiction and *The Inventor's Secret* is nonfiction.)

Refer to the part of the story where Rosie feels discouraged because her flying machine didn't work (pp. 18–21), but her great-great-aunt Rose tells her, "Your brilliant first flop was a raging success! Come on, let's get busy and on to the next!" Explain that an important part of engineering is dealing with failures and learning from them. Then, read the last line of page 27, "Life might have its failures, but this was not it. The only true failure can come if you quit." Explain that engineers often try many designs before they find one that works best and that to be a good engineer you must persevere through failed attempts. Failures give engineers a chance to go back and improve on their original idea until they solve the problem.

evaluate

Balloon Car Challenge, Part 3: Redesign, Build, Test & Evaluate, and Share Solution

Tell students that you would like them to apply the design process they learned about in the explain phase of this lesson to their balloon car design challenge. Refer to the poster, point out each step, and ask students how they have addressed each step so far. Here are the answers:

- Identify Problem: The problem was provided for us—design a balloon car.
- Brainstorm: We brainstormed as a class and watched a video for more ideas.
- Design: We sketched our ideas.
- Build: We built our cars with the supplies.
- Test & Evaluate: We tested them to see if they met the criteria in the design challenge.

Tell students that now it is time to complete the remaining steps of the process—Redesign and Share Solution. *Ask*

? Did your first car meet the criteria for success presented in the design challenge?

Testing balloon cars

? Can you think of ways to make it go farther on one balloonful of air?

? Can you think of any other ways to improve it?

Tell students that you would like them to think of the first version of the car they built as their "Model A." Encourage students to redesign, rebuild, and test their car to make it work better. Point out on the poster that Redesign, Build, and Test & Evaluate are parts of a cycle and they will need to repeat all of those steps until they have a prototype they are satisfied with and ready to share. Explain that a *prototype* is a working model of a product, usually the last model before the design goes into production. Explain that it is important to keep track of each change they make and the affect the change has on the motion of the car. Give each student a copy of the Redesign, Build, Test & Evaluate student page. On the table, they can keep track of how each change affected the motion of the design. Tell students it is important to test one change at a time to know how that change affected the motion of the car. If they change more than one thing at time, then it will be difficult to determine what change made the difference. Remind students of the inventor's secret—"Keep at it!" You may even want to create a sign to hang in the classroom with Edison's encouraging words on it.

Connecting to the Common Core
Reading: Informational Text

Integration of Knowledge and Ideas: 3.9, 4.9, 5.9

Finally, when students are satisfied with their designs, have them share their balloon car prototype with the class by demonstrating how it works and then displaying it. Create display cards by copying the Display Card student page on cardstock. Have students fill out the information on the card (name, model letter, distance traveled, criteria met and constraints taken into account checked off) and fold it in half to create a table tent to put next to their models.

STEM at Home

Have students complete the "I learned that …" and "My favorite part of the lesson was …" portions of the STEM at Home student page as a reflection on their learning. They may choose to do the following at-home activity with an adult helper and share their results with the class. If students do not have access to the internet or these materials at home, you may choose to have them complete this activity at school.

"At home, we can watch a short video on the *Design Squad Global* website from PBS Kids."

Visit http://pbskids.org/designsquad/video *and choose a design challenge video to watch.*

"After we watch the video, we can discuss these questions:

1. What problem was the design squad trying to solve?
2. What parts of the design process did you observe in the video?
3. Which idea do you think would work best?"

For Further Exploration

This section is provided to help you encourage your students to use the science and engineering practices in a more student-directed format. This box lists questions and challenges related to the lesson that students may select to research, investigate, or innovate. Students may also use the questions as examples to help them generate their own questions. After selecting one of the questions in the box or formulating their own questions, students can individually or collaboratively make predictions, design investigations or surveys to test their predictions, collect evidence, devise explanations, design solutions, or examine related resources. They can communicate their findings through a science notebook, at a poster session or gallery walk, or by producing a media project.

Research

Have students brainstorm researchable questions:

- How many patents does Thomas Edison have? What are some of his lesser known inventions?
- How did Henry Ford's assembly line change American industry?
- What kinds of engineers are involved in car design?

Investigate

Have students brainstorm testable questions to be solved through science or math:

- Which balloon car in your class goes the farthest?
- Which balloon car in your class goes the fastest?
- What do your classmates think the best invention of all time is? Take a survey! Graph the results, then analyze your graph. What can you conclude?

Innovate

Have students brainstorm problems to be solved through engineering:

- Can you design a way to mass produce your best model car?
- Can you invent something to solve an everyday problem?
- Can you design a reminder (poster, bookmark, etc.) for your classmates to "Keep at it!" when they get discouraged with a task or challenge?

Reference

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

Websites

Design Squad Global
http://pbskids.org/designsquad

Design Squad Global "4-Wheel Balloon Car" (video)
http://pbskids.org/designsquad/build/4-wheel-balloon-car

Rosie Revere, Engineer: Engineering and Discovery With Author Andrea Beaty (video)
www.youtube.com/watch?v=EymQZsv9Me8

More Books to Read

Barretta, G. 2012. *Timeless Thomas: How Thomas Edison changed our lives.* New York: Henry Holt and Company.
Summary: This clever book shows modern-day devices that had their beginnings in Edison's lab. Colorful, and at times humorous, illustrations depict Edison and his team of employees working in the lab, while the opposite side of each page shows present-day versions of his inventions. End matter includes a time line of Edison's most famous inventions and short bios of some of his employees.

Brown, D. 2010. *A wizard from the start: The incredible boyhood and amazing inventions of Thomas Edison.* New York: Houghton Mifflin.
Summary: This "storyography" depicts Thomas Edison's life from his humble beginnings as a farmer's son selling newspapers on trains and reading through public libraries shelf by shelf, to his inventing career, to eventually his becoming a world-renowned legend.

Editors at Time for Kids. 2005. *Thomas Edison: A brilliant inventor*. Time for Kids Biographies. New York: HarperCollins.
Summary: This book gives readers an up-close look at the life and work of Thomas Edison and is illustrated with historical and contemporary photographs.

Editors at TIME for Kids. 2008. *Henry Ford: Putting the world on wheels.*Time for Kids Biographies. New York: HarperColins.
Summary: This book gives readers an up-close look at the life and work of Henry Ford and is illustrated with both historical and contemporary photographs.

Mortensen, L. 2007. *Thomas Edison: Inventor, scientist, and genius.* Minneapolis, MN: Picture Window Books.
Summary: Simple text and whimsical illustrations depict the life of Thomas Edison from his childhood antics to the inventions that changed the world.

PBS. 2016. Design squad global. Parents and educators: Online workshop. *http://pbskids.org/designsquad/parentseducators/workshop/process.html.*

Spires, A. 2014. *The most magnificent thing.* Tonawanda, NY: Kids Can Press.
Summary: One day, a little girl decides she is going to make the most magnificent thing! She knows just how it will look. She knows just how it will work. But making the most magnificent thing is harder than she thinks.

Name : ________________________________

Balloon Car Design Challenge

Problem: Design a balloon-powered car.

Criteria (desired features or outcomes):

1. Must be powered by a balloon
2. Must travel in a straight line
3. Must travel at least 30 cm on one full balloon of air

Constraints (limits on available resources and time):

1. Materials: You may use only materials provided by or approved by your teacher.
2. Time: You must build your balloon car within the time limit set by your teacher.

Sketch your ideas.

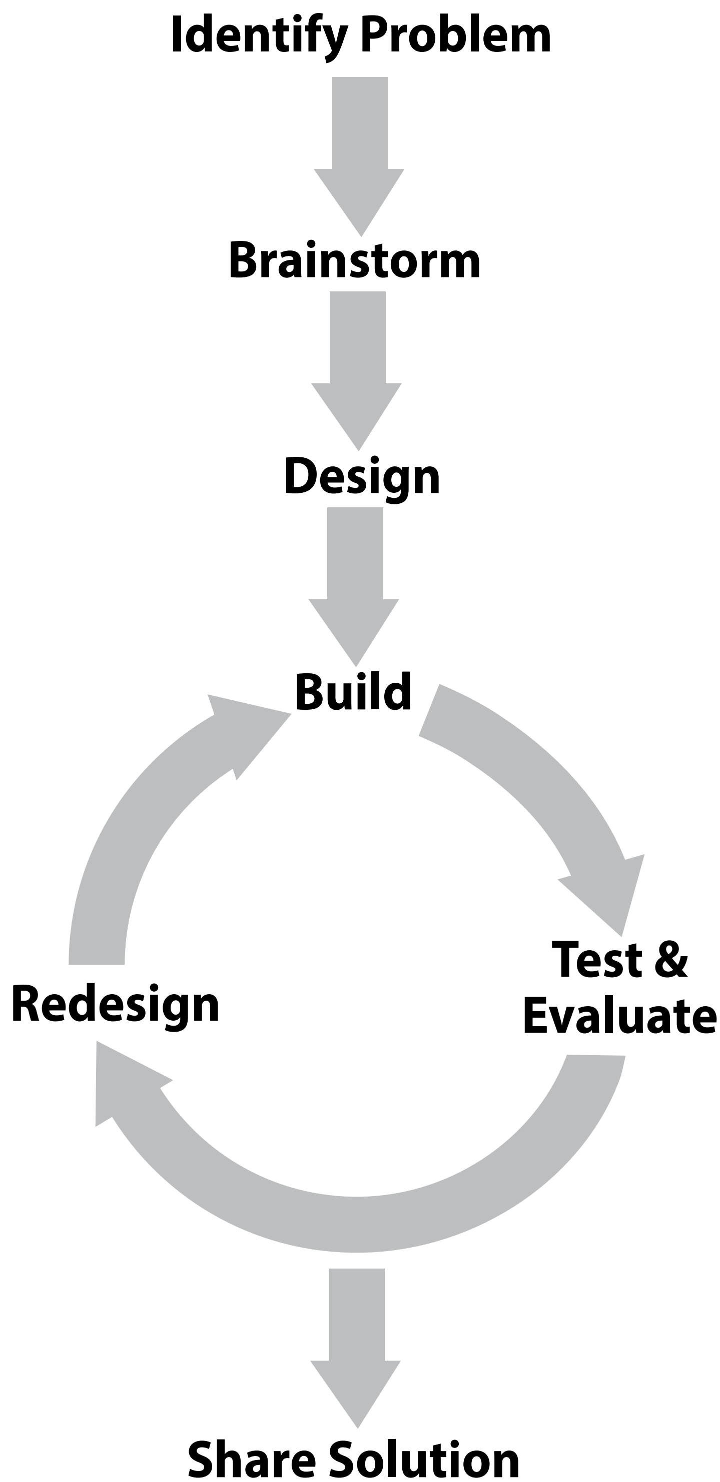
How will you test your design? ____

____

____

Teacher Checkpoint: ☐

The Design Process

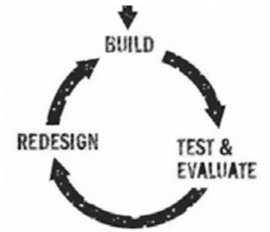


Edison Quotes

Genius is 1% inspiration and 99% perspiration. —Thomas Edison
I have not failed. I have just found 10,000 ways that do not work. —Thomas Edison
Our greatest weakness lies in giving up. The most certain way to succeed is to try just one more time. —Thomas Edison
Just because something doesn't do what you planned it to do, doesn't mean it's useless. —Thomas Edison
I never did a day's work in my life. It was all fun. —Thomas Edison
I have friends in overalls that I would not swap for the favor of the kings of the world. —Thomas Edison
To invent, you need a good imagination and a pile of junk. —Thomas Edison
If we did all the things we were capable of, we would literally astound ourselves. —Thomas Edison

Name : ________________________

Redesign, Build, Test & Evaluate



Use the Redesign, Build, Test & Evaluate Cycle to improve your car. Record each change you make in the table below and then record the distance each model travels and any observations about its motion.

Model	Change to Design (Example: Changed the wheels to a different material)	Distance Traveled (cm)	Observations
A	No change, original design		

Name : ______________________________

Prototype Display Card

Engineer ____

Model ______________ Distance Traveled ____________________

Criteria Met (✓)

- ☐ Powered by a balloon
- ☐ Moves in a straight line
- ☐ Travels a distance of at least 30 cm on one full balloon of air

Within Constraints (✓)

- ☐ Materials: Built with only approved materials
- ☐ Time: Built within the time limit

Name : ___________________________________

STEM at Home

Dear ___________________,

At school, we have been learning about the **design process.**

I learned that: ____

____

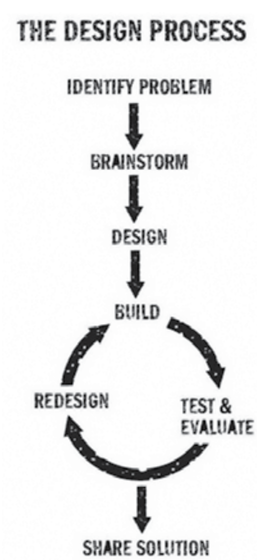
My favorite part of the lesson was: ______________________________

____

____

At home, we can watch a short video on the *Design Squad Global* website from PBS Kids.

Visit ***http://pbskids.org/designsquad/video*** and choose a Design Challenge Video to watch.



After we watch the video, we can discuss these questions:

What problem was the design squad trying to solve?

____

____

What parts of the design process did you observe in the video?

____

____

Which idea do you think would work best? ____________________

____

____

Index

Page numbers printed in **boldface type** indicate tables, figures, or illustrations.

Picture-Perfect STEM Lessons, 3–5

Using Children's Books to Inspire STEM Learning

"Teachers in our district have been fans of *Picture-Perfect Science* for years, and it's made a huge impact on how they fit science into their school day. We are so excited to do more of the same with these *Picture-Perfect STEM* books!"
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