FEATURE ARTICLE

stories of design:

using books to unpack the engineering design process

by Michelle Forsythe, Judy Jackson, and Danielle Medeiros

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Take a glance around any place there are young children—a home, a schoolroom, or even an informal learning center—and you'll most likely find a stack of books.

The right book provokes curiosity, challenges misconceptions, raises intriguing problems, and inspires children to experience the world through someone else's eyes. Both the National Academy of Engineering (NAE) and the International Technology and Engineering Educators Association (ITEEA) recommend that teachers and parents use books to introduce children to the diverse ways in which engineers have impacted our world. "Stories that dramatize the rich legacy of engineering achievements" can "bring the experience of engineering to life" (NAE, 2008, p.44). Problems presented in children's stories can also be used to launch engineering design challenges. For example, *Standards for Technological Literacy: Content for the Study of Technology* details how a teacher can use the story *Mike Mulligan and His Steam Shovel* to initiate an investigation of how to get a miniature steam shovel out of a hole dug in a tub of wet sand (ITEA, 2007).

In our work with elementary students, we take these recommendations one step further by also using books to reverse-engineer the processes by which engineers solve problems. Like Hill-Cunningham, Mott, and Hunt (2008), we view children's literature as providing a "real life" application for the engineering design process (EDP). Most often, we use trade books and picture book biographies of engineers and inventors with younger students and chapter book biographies with older students. Biographies are particularly effective for exploring the EDP because they present a "chronological sequence of events with a framework that assists readers in developing their understanding about the person-of-study and that individual's achievements" (Werderich, Farris, & McGinty, 2014, p.66).

Figure 1. EDP stages in *Whoosh! Lonnie Johnson's Super-Soaking Stream of Inventions*

	EDP Stage	Summary of excerpt from *Whoosh!*
Robot	Imagine	Lonnie is inspired by a TV show to build a robot.
	Create & Test	He gets his robot to turn and move.
	Improve	But he struggles to get the transmitter to work.
	Create & Test	He uses his sister's walkie-talkie to fix the robot's transmission issue.
Galileo probe	Ask	NASA needs a back-up power system for Galileo probe.
	Imagine	Lonnie comes up with a solution.
	Communicate	He shares his ideas, but some at NASA doubt him.
	Create & Test	Lonnie builds his power system, and it works.
Super Soaker	Ask	Refrigerators and air conditioners need a new cooling system.
	Imagine	Lonnie thinks water and air pressure might solve the cooling problem.
	Create & Test	He makes a pump and nozzle and tests them with a faucet.
	Imagine	The stream blast gives Lonnie the new idea to make a water gun.
	Ask	Lonnie needs to make parts that kids can handle.
	Create & Test	He builds a prototype and tests it out at a picnic.
	Communicate	He fails to convince toy companies to make his water gun.
	Create & Test	Lonnie keeps working on other projects.
	Improve	He makes a revised prototype with a new tank.
	Communicate	A toy maker is impressed by his invention. The Super Soaker is born!
	Ask	Lonnie is still in his workshop solving problems!

The EDP details a series of iterative actions that guide engineers as they investigate problems and construct, refine, and communicate solutions. Although there are several accepted versions of the EDP, most versions feature a cycle by which engineers "continually enhance and improve their design through repeated testing, analysis, and redesign" (Parker, Smith, McKinney, & Laurier, 2016, p. 400). When working with young children, we typically use the version of the EDP developed by The Museum of Science, Boston as part of its Engineering is Elementary project (Cunningham, 2009). This easy-to-understand EDP model features five stages: Ask, Imagine, Plan, Create & Test, and Improve. Although we use this specific EDP model throughout this article, we have found that most models of engineering design can be reverse-engineered using well-chosen biographies and trade books.

To initially unpack the EDP, we read aloud to the class a biography about an engineer or a trade book that contains an obvious problem. As we read, we pause to connect key story elements and actions to the EDP. The complexity of how students perceive these EDP stages builds as they re-encounter these stages at different moments throughout the book. For example, Figure 1 outlines the progression of EDP stages in the book *Whoosh! Lonnie Johnson's Super-Soaking Stream of Inventions* (Barton, 2016). This book explores Lonnie Johnson's journey as an inventor, including his creation of the hit Super Soaker toy. Later, students formalize their understanding of the EDP by creating a presentation, a project, or an artifact that summarizes the problem (or problems) that the characters faced and how they used each component of the EDP to solve that problem. These integrated literacy and STEM activities support students' holistic understanding of design and align with Standards 8, 9, and 10 of *Standards for Technological Literacy* (ITEA/ITEEA, 2007).

Because the EDP is a cycle, it may be entered at any point. However, it is not a linear process. Consequently, "it is important that [students] realize that these steps do not have to be completed in a set sequence. Rather, they should be completed in any sequence that will produce the best results" (ITEEA, 2007, p. 102). One of the strengths of using biographies and trade books to explore the EDP is that the "messiness" of this sequence is often evident in the storyline. For example, as was seen in Figure 1, when Lonnie Johnson tested his design for a new refrigerator system, the test inspired him to think of a way to create a new toy.

Figure 2. Students using response sticks to identify the EDP stages.

Figure 3. Students using sticky notes to identify the EDP stages.

After the first collective unpacking of the EDP, we have students track and report the unique stages of the EDP that occur during new stories. Students can create response sticks labeled with each EDP stage (Figure 2). Then, during class read-alouds, the students can raise the corresponding response stick whenever they notice a particular EDP stage in action. The first few times that we use this reading-comprehension strategy, we typically focus students' attention by having each student be responsible for only one or two EDP stages. However, as students' literacy skills and their knowledge of the EDP grow, each will eventually work with the entire set of EDP stages. A similar literacy strategy using sticky notes instead of response sticks can be used during individual silent reading (Figure 3). Students can place a sticky note labeled with an EDP stage on the page where they notice that stage in action. Once students are familiar with the EDP, we often give them a blank EDP template (Figure 4) to fill in during a class read-aloud or individual reading. Sometimes we add a sixth EDP stage—communicate—to the blank space in the bottom left corner. With all of these strategies, it is important that students not only identify the EDP stage, but that they also justify their selection. We use probing questions and facilitated student-to-student talk to elicit and discuss the ways that students are interpreting the engineer's actions in the book.

Engineering is Elementary project of The Museum of Science, Boston includes children's literature suggestions within the content area connections section of its curriculum, which can be found at www.eie.org/eie-curriculum/eie-content-area-connections#alarms.

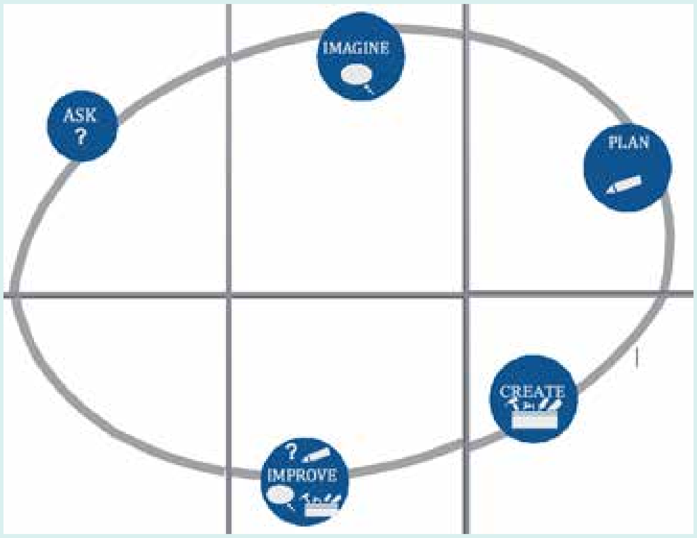


Figure 4. Blank EDP template.

Although at first it might seem daunting to find an appropriate book to reverse-engineer the EDP, this journal as well as other publications have compiled lists of books that have been vetted by experienced STEM educators. These resources offer reliable starting points to look for trade books that promote students' STEM learning (Authors, in press). For example, this journal has long formatted a column called "Books to Briefs" that models how to use books to launch an engineering design challenge. Many of these book selections can also be used to explicitly trace the EDP in action. Likewise, each year the National Science Teachers Association (NSTA) reviews recently published trade books and issues a list of the Best STEM Books K–12, which can be found at www.nsta.org/publications/stembooks/. In addition, the NSTA journal *Science and Children* includes a "Teaching Through Trade Books" column that recommends two STEM books per issue. Finally, the

Examples of picture book biographies, chapter biographies, and other trade books that we have used to unpack the EDP can be found in Table 1. Picture book biographies include simplified text and informative illustrations that present a snapshot of the problem-solving process of an engineer or inventor. The picture book biography *Balloons Over Broadway: The True Story of the Puppeteer of Macy's Parade* reveals the many roadblocks and redesigns involved in making the famous Macy's parade balloons. Chapter book biographies typically dig more deeply into the life of an engineer or inventor, as each chapter often details a different key moment, place, or problem in their lives. The chapter book *Who Were the Wright Brothers?* explores how Orville and Wilbur Wright applied their observations of birds and their understanding of bicycles to design the first successful flying machine (Buckley, 2014). Other fiction and nonfiction trade books that include a problem, a review of a plan of action, the creation and testing of a prototype, or a reasonable, workable solution can also be used to unpack the EDP. The trade book *The Most Magnificent Thing* weaves a story of the frustration and eventual success that often accompanies the "create & test" and "improve" phases of the EDP.

In this article we have focused on using books to unpack the EDP. However, similar literacy strategies can also be used to explore engineering habits of mind, such as systems thinking, creativity, optimism, collaboration, communication, and ethical considerations (Katehi, Pearson, & Feder, 2009). Teachers can pass out response sticks labeled with these habits of mind. Then, as the teacher reads the biography or trade book aloud, students can raise the corresponding response stick whenever they notice a character in the story using a specific engineering habit of mind. When this happens, the teacher can

Table 1. Picture book biographies, chapter biographies, and other trade books for unpacking the EDP.

Picture Book Biographies	Chapter Book Biographies	Other Trade Books
▪ *Balloons over Broadway: The True Story of the Puppeteer of Macy's Parade* ▪ *Manfish: A Story of Jacques Cousteau* ▪ *The Marvelous Thing That Came From a Spring: The Accidental Invention of the Toy That Swept the Nation* ▪ *Mr. Ferris and His Wheel*	▪ *Frozen in Time: Clarence Birdseye's Outrageous Idea About Frozen Food* ▪ *The Inventions of Alexander Graham Bell* ▪ *Shoes for Everyone: A Story of Jan Matzeliger*	▪ *Ada's Violin: The Story of the Recycled Orchestra of Paraguay* ▪ *The Most Magnificent Thing* ▪ *Rosie Revere, Engineer*

pause the reading and ask the students to explain how the character applied that particular habit of mind to solve a problem or address a challenge.

Engineers use the habits of mind and the EDP to systematically and efficiently solve problems and design new innovations. Parents and teachers can use biographies about engineers and trade books with identifiable problems to reveal the nature of what engineers do and enable students to connect to the actions of engineering design. Although STEM educators have often used books to create briefs for launching engineering challenges, Foster (2009) has recommended that educators also "increase the degree to which the activities bolster reading comprehension." Our approach to using biographies and trade books to unpack the EDP presents one way to integrate more sophisticated literacy strategies within engineering lessons.

references

Barton, C. (2016). *Whoosh!: Lonnie Johnson's super-soaking stream of inventions.* Watertown, MA: Charlesbridge.

Beaty, A. (2013). *Rosie Revere, engineer.* New York, NY: Abrams Books for Young Readers.

Berne, J. (2008). *Manfish: A story of Jacques Cousteau.* San Francisco, CA: Chronicle Books.

Buckley, J. (2014). *The Wright brothers.* New York, NY: Penguin Random House.

Cefrey, H. (2003). *The inventions of Alexander Graham Bell: The telephone (19th Century American Inventors).* New York, NY: PowerKids Press.

Cunningham, C. M. (2009). Engineering is Elementary. *The Bridge, 30*(3), 11–17.

Davis, K. G. (2014). *Mr. Ferris and his wheel.* New York, NY: HMH Books for Young Readers.

Ford, G. (2016). *The marvelous thing that came from a spring: The accidental invention of the toy that swept the nation.* New York, NY: Atheneum Books for Young Readers.

Foster, P. N. (2009). An analysis of children's literature featured in the "Books to Briefs" column of *Technology and Children*, 1998–2008. *Journal of Technology Education, 21*(1), 25–43.

Hill-Cunningham, P. R., Mott, M., & Hunt, A-B. Facilitating an elementary engineering design process module. *School Science and Mathematics, 118*(1-2), 253-260.

Hood, S. (2016). *Ada's violin: The story of the recycled orchestra of Paraguay.* New York, NY: Simon & Schuster.

International Technology Education Association. (ITEA/ITEEA). (2007). *Standards for technological literacy: Content for the study of technology* (3rd ed.). Retrieved from www.iteea.org/File.aspx?id=67767&v=b26b7852

Katehi, L., Pearson, G., Feder, M. (2009). The status and nature of K-12 engineering education in the United States. *The Bridge, 39*(3), 5–10.

Kurlansky, M. (2014). Frozen in time: *Clarence Birdseye's outrageous idea about frozen food.* New York, NY: Random House.

Mitchell, B. (1986). *Shoes for everyone: A story of Jan Matzeliger.* Minneapolis, MN: Carolrhoda Books, Inc.

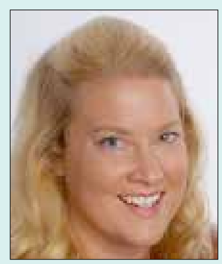
National Academy of Engineering. (2008). *Changing the conversation: Messages for improving public understanding of engineering.* Washington, DC: National Academies Press.

Parker, C., Smith, E., McKinney, D., & Laurier, A. (2016). The application of the engineering design proves to curriculum revision: A collaborative approach to STEM curriculum refinement in an urban district. *School Science and Mathematics, 116*(7), 399-406.

Spires, A. (2014). *The most magnificent thing.* Tonawanda, NY: Kids Can Press.

Sweet, Melissa. *Balloons over Broadway: The true story of the puppeteer of Macy's parade.* New York: NY: Houghton Mifflin, 2011.

Werderich, D., Farris, P., & McGinty, A. (2014). Biography as mentor. *Science and Children, 52*(2), 66-69.



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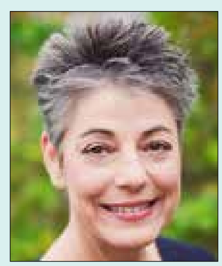

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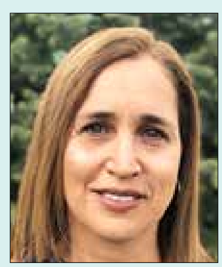

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