Engineering Encounters

Creating a classroom culture for engineering

Elephant Trunks and Dolphin Tails

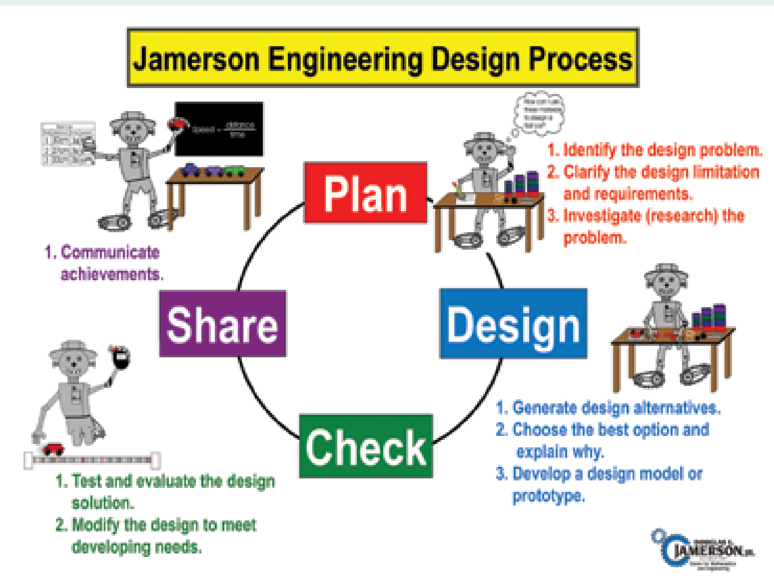
An elephant-trunk design challenge introduces students to engineering for animals.

By Lukas Hefty

"How do engineers help animals?" Mrs. Hefty, a second-grade teacher at Douglas Jamerson Elementary School in St. Petersburg, Florida, begins many lessons with this type of leading question. Talking about engineers and how they impact society is routine at Jamerson, a center for engineering and mathematics. All students in kindergarten through fifth grade engage in teacher-created, integrated engineering units of study, purposefully aligned to the *Next Generation Science Standards* for engineering design and the *Common Core State Standards* for English language arts and mathematics. The school's vision, "Engineering innovative thinkers for global success," comes to life as students develop the habits of mind—curiosity, creativity, critical thinking, perseverance, and communication—that successful innovators possess. The centerpiece of the curriculum is the Jamerson Engineering Design Process (see Figure 1), through which students collaborate to identify real-world problems, *plan* multiple solutions and select the most efficient one, *design* models and prototypes to *check* against rigorous design constraints, and *share* their findings.

FIGURE 1.

Engineering design process.



"How do engineers help animals?" Mrs. Hefty repeats. The students seem unsure and confused. In kindergarten and first grade they were exposed to engineers who design bridges and skyscrapers, "just right" chairs, and aerodynamic ships. But animals? After some time to brainstorm together, they come up with a few ideas: engineers may help veterinarians heal sick animals or zookeepers develop safe habitats. Mrs. Hefty reads aloud the nonfiction text *Pierre the Penguin* by Jean Marzollo (2010). After molting, as all penguins do, Pierre's feathers did not grow back. Engineers at the California Academy of Sciences designed a wetsuit to keep Pierre warm, with an unexpected side effect—Pierre grew his feathers back. After reading, the class watches a brief news clip about Pierre and views the California Academy of Sciences live penguin webcam, learning more about penguin behaviors like preening and molting. The class uses the Jamerson Design Process to identify Pierre's main problem and the steps taken by engineers to develop a solution. The students are hooked, excited to discover more about how engineers help animals.

Mrs. Hefty opens the next day with a related question: "Has anyone heard of Winter the Dolphin?" Hands shoot up as students begin to retell the movie *Dolphin Tale* (2011). Rescued from a crab trap off a Florida coast and without a tail, Winter had little chance of survival. While veterinarians and scientists at the Clearwater Marine Aquarium fought to keep Winter alive, engineers spent six months designing a prosthetic tail, inventing brand-new materials and working through over 100 prototypes. Winter's successful recovery has led to breakthroughs in prosthetic technology used to help returning war veterans. The class views a news clip outlining Winter's story and examines photographs of the prosthetic tail. In groups of three, the students use *www.seewinter.com* to investigate how engineers used each step of the engineering design process to help Winter. What stands out most for students are the number of models developed before they found one that fit just right. "Those engineers really had to persevere," one boy remarks. Perseverance, the understanding that *failure* is an opportunity to redesign, is a concept not lost on Jamerson teachers.

The Engineering Design Challenge

"Now it's your turn to be the engineer!" Mrs. Hefty announces excitedly. "We have a problem: The zoo just rescued an elephant that doesn't have a trunk!" The classroom buzzes with excitement. "Why would an elephant without a trunk be a problem?" The students share ideas about the importance of the elephant's trunk: smelling, grabbing objects, and so on. The class decides to research elephant trunk physical characteristics and functions at *www.seaworld.org*. The students are surprised at the number and variety of functions they discover: grasping, breathing, feeding, dusting, smelling, drinking, lifting, sound production and communication, defense and protection, and sensing. The trunk contains an estimated 100,000 muscles, providing the ability to expand, contract, and move in all directions (crosscutting concept: Cause and Effect). In other words, an elephant without a trunk is no small problem. This aligns with the *Next Generation Science Standards* Engineering Design performance expectation K-2-ETS1-1: Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool, as well as disciplinary core idea ETS1.A: Defining and Delimiting Engineering Problems.


PHOTOGRAPHS COURTESY OF THE AUTHOR

Measuring the trunk.

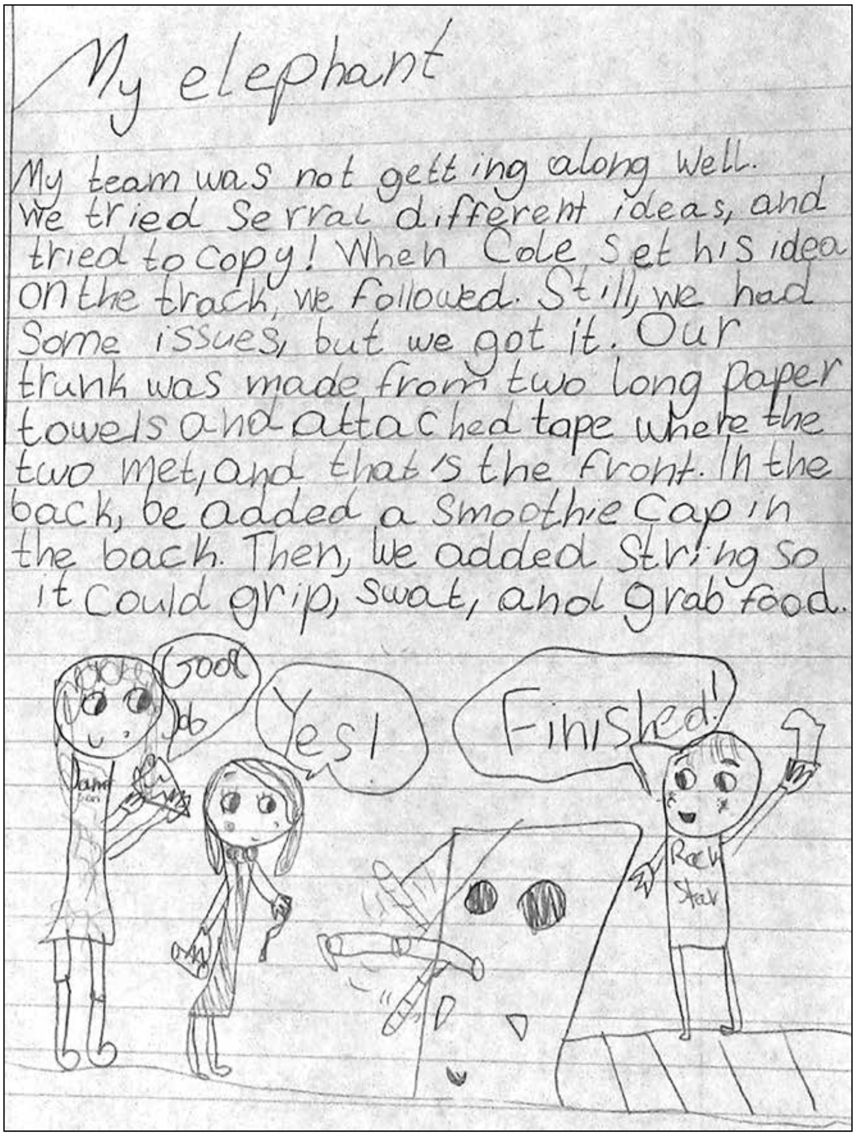
Mrs. Hefty continues, "Let's put on our engineer hats." She pauses for all of the students to "put on their hats." This week we are working as biomedical engineers, just like the ones who helped Pierre and Winter. Your challenge is to design a model prosthetic trunk for the rescued elephant, with the following design constraints:

- The trunk length must be 50–80 cm.
- The trunk must enable the

elephant to breathe. (It should include "nostrils," or an opening that would allow for breathing.)

- The trunk must attach to the body (a science show board with an elephant body drawn and a hole for the trunk).
- Your team must use the Jamerson Design Process and the materials provided (science and engineering practice: Developing and Using Models).

Jamerson teachers consider ability levels, background and cultural experiences, and other special needs to intentionally form heterogeneous student teams. The teams examine the teacher-provided materials—paper towel rolls, construction paper, foil, string, and other craft supplies—and are also asked to brainstorm materials they could bring from home. One group decides to bring in a pool noodle to serve as the trunk. Using the design challenge handout (see NSTA Connection) as a guide, the students begin talking about potential solutions. They review the physical characteristics and functions of an elephant trunk, consider the available materials, and draw individual sketches. Each child presents an idea, and the team discusses the positives and potential drawbacks. "Will that design allow the elephant to breathe? Could we use more flexible materials? How can we make it look more realistic?" (disciplinary core idea ETS1.A: Defining and Delimiting) The formation of diverse student teams allows the students to support one another in the development of the *best* idea. Eventually each team comes to consensus and draws an agreed-upon diagram. Over several days the students work together to construct a model, check it against the design constraints, and make revisions to their diagram and physical model. They measure length and diameter and test for flexibility and strength. They are asked to consider factors such as whether the trunk will stretch and contract and the extent to which it will twist and bend without breaking (ETS1.B: Developing Possible Solutions).



A student reflects on how well his team worked together.

Finally they attach the trunk to the display board. Although each model looks different, every group reaches some level of success; engineering design performance expectation K-2-ETS1-2: Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.

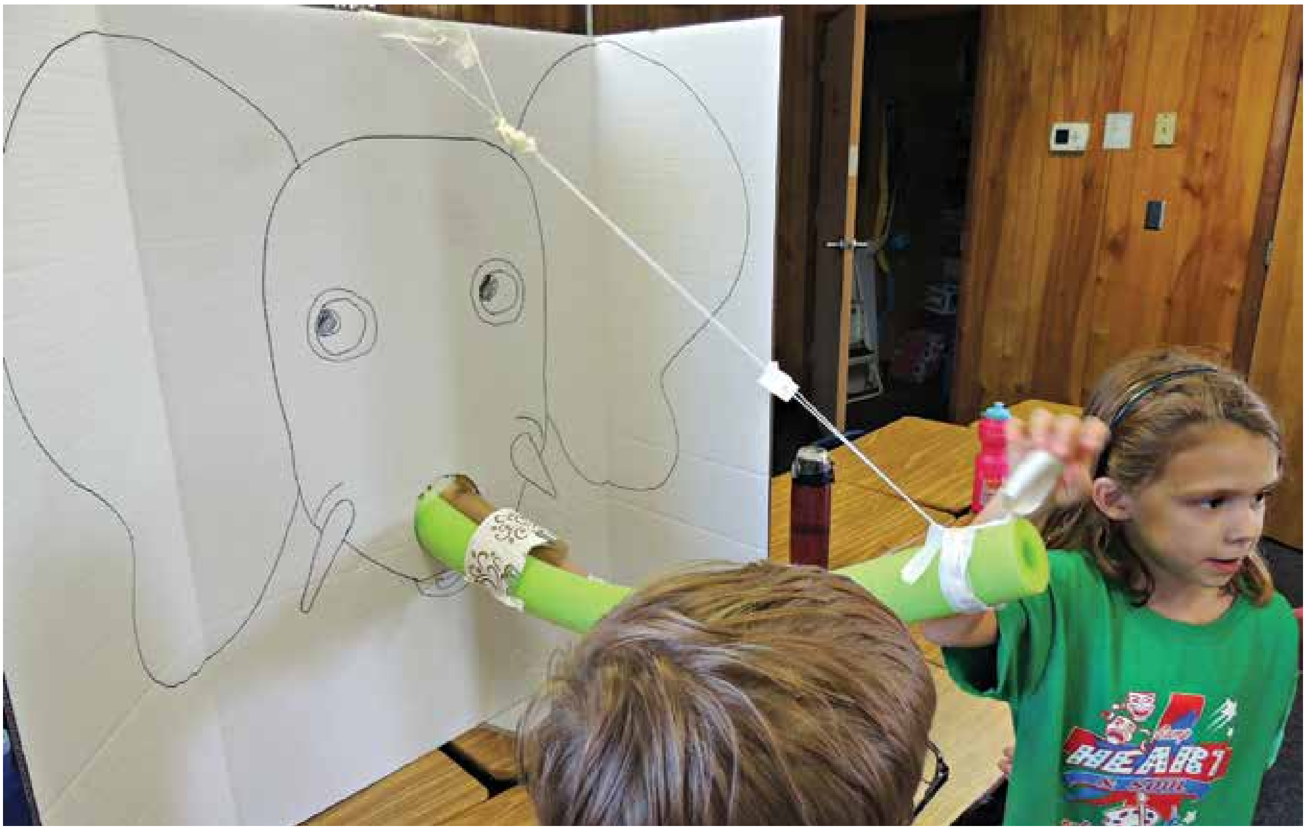
Like all good scientists and engineers, the teams share their findings, developing a written report and an oral class presentation. They consider points such as what did and did not go well, how the team cooperated, how many times they revised their model, and the final dimensions and materials used. The students are eager to share their displays but also to see and hear what other teams discovered.

Science and Engineering

This series of lessons lasted approximately two weeks, 45 minutes per day, and were the conclusion to an integrated unit of study entitled "Nature of Science and Engineering." Taught at the beginning of the school year, the unit focuses on the comparison of scientific and engineering practices in preparation for a year of similar, real-world design investigations. It assists with building a collaborative, respectful classroom culture. The overarching goal of the K–5 integrated engineering curriculum is to develop in students the knowledge, skills, and habits of mind of successful scientists and engineers. While creating each unit of study, teachers consider the following:

1. *How can we level the playing field for students with varied background knowledge and learning styles?*

   Beginning in kindergarten, Jamerson students are exposed to complex academic language. In many cases vocabulary words are never explicitly taught but modeled by teachers during everyday engineering lessons. Over time the students begin to appropriately use terms like *prototype* and *design constraint*, to discuss the metric system, and to describe



A team attaches its trunk to the display board.

how they used each step in the engineering design process. In the vignette above, the use of articles, websites, and media exposed students to content in multiple ways. Techniques for online research and note-taking were modeled, and responsibility was released gradually from the teacher to the students. Background knowledge was developed over multiple days prior to the design challenge, which leveled the playing field for students without prior experience with a topic, or with a specific learning challenge. This increased collaboration and active participation from all students during the challenge.

2. *Does the engineering design challenge allow for creativity?*

   While all students utilize an engineering design process and are bound by the same design constraints, multiple solutions are possible and expected. Groups may achieve different levels of success, and two successful models may look very different from each other. Students with academic challenges or learning disabilities often do particularly well when given the opportunity to be creative.

3. *Does the design challenge encourage perseverance?*

   Engineers in the real world will develop multiple, in many cases, hundreds of prototypes. They travel back and forth between design process stages, experiencing "failure" many times, which informs improvement and eventual success. The ability to persevere through setbacks and frustrations, design flaws, and disagreements with teammates, develops character that transcends any single subject area. This may be the single most important benefit of exposing children to engineering design challenges in elementary school, and enough time must be allotted to allow for such repeated failure.

4. *How are collaboration and communication skills developed?*

   Important to most jobs, these qualities are essential to an engineer's. During the planning stage of the elephant trunk design challenge, the second-grade students began by thinking independently then shared their ideas and sketches with teammates. Interestingly, it was not necessarily the "best" idea that was accepted by the team but the idea that was most effectively communicated. Often the "gifted" learners came up with unique solutions but were not able to communicate them effectively to teammates, a skill that takes substantial practice to develop. Teams that had difficulty communicating were less likely to develop a design within the time constraint. During the share stage, students had to communicate results orally and in writing. Over the next three years, these second graders will learn to publish their final reports, develop data tables and graphs, and create multimedia presentations to share their findings.

5. *How will student learning be assessed?*

   Engineering design challenges at Jamerson are the culmination of a five-week unit of study, wherein students have the opportunity to apply learning to a performance-based task. The design challenge handout serves as a guide for students and includes a checklist or rubric based on the specific task's expectations. The scoring rubric (see NSTA Connection) is shared with students when the challenge is introduced and includes categories such as teamwork, design product, and final report. For the elephant trunk design challenge, a separate section of the scoring rubric outlines the expectations for the written report.

When developing integrated engineering units of study, Jamerson teachers consider the following:

1. Which science core ideas will be the focus?
2. Which standards for engineering design will be included?
3. Which Common Core ELA and Mathematics standards, and which social studies standards, can be naturally embedded?
4. How can we assess student learning (engineering design challenge)?
5. What knowledge and skills will the students need to be successful with the engineering design challenge (individual lessons)?

In beginning the seemingly daunting task of teaching engineering concepts to elementary-age students, the above steps can help, but the lead teachers at Jamerson also offer the following tips:

- *Start Simple*
  Begin with the science units you already teach, and add related engineering concepts and design challenges. This will ensure that learning is purposeful and standard-based rather than a set of disconnected engineering activities.
- *Collaborate*
  Sharing the burden with colleagues will lessen the individual load and improve the product. It also provides a similar experience to what the students will face.
- *Reflect and Revise*
  Every engineering lesson will have unexpected outcomes, both good and bad. Like a design product, an engineering lesson will require several prototypes.

Conclusion

The Nature of Science & Engineering unit described sets the stage for a year of learning to collaborate and communicate with a diverse team using the engineering design process. It aligns with a coherent K–5 engineering curriculum that balances knowledge and practice. When we ask our kids to think like engineers—to define and design solutions to meaningful problems—we as teachers must make an uncomfortable shift by allowing our students to struggle and even fail. This requires a significant amount of time and patience, but those who make the shift over time will watch their students experience success through their failures and become highly motivated, thoughtful citizens. ■

Connecting to the Standards

Standard: K-2-ETS1 Engineering Design

Performance Expectations:

K-2-ETS1-1: Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.
K-2-ETS1-2: Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.

Science and Engineering Practice:

Developing and Using Models

Disciplinary Core Ideas:

ETS1.A: Defining and Delimiting Engineering Problems
ETS1.B: Developing Possible Solutions

Crosscutting Concept:

Structure and Function

NGSS Table: K-2-ETS1 Engineering Design
www.nextgenscience.org/k-2ets1-engineering-design

***Lukas Hefty** (heftyl@pcsb.org) is the Magnet Program Coordinator at Douglas L. Jamerson Jr. Elementary School in Pinellas County, Florida.*

References

Dolphin Tale. Film. Directed by Charles Martin Smith. 2011.Burbank, CA: Warner Bros., 2011. DVD.
Marzollo, J. 2010. *Pierre the penguin.* Ann Arbor, MI: Sleeping Bear Press.
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.*

Internet Resources

Clearwater Marine Aquarium
www.seewinter.com
SeaWorld
www.seaworld.org

NSTA Connection

Visit *www.nsta.org/SC1412* for the design challenge handout, scoring rubric, and a sample lesson plan.