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Exploring Science and Engineering Practices in Children’s Picture Books

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by Dr. Derrick Nero and Dr. Kathleen Danielson

Reports by the National Research Council (NRC) provided the basis for the Next Generation Science Standards (NGSS) over ten years ago with an emphasis on critical thinking and communication skills through science that prepare students for college and careers after high school (2006, 2009, 2012, 2013). NGSS (2013) operationalized the three dimensions of learning, Disciplinary Core Ideas, Crosscutting Concepts, and Science and Engineering Practices, of NRC's influential work as a hub for its student learning objectives. The focus on Three-Dimensional Learning has allowed NGSS to be adopted nationwide as the state Science Standards in 20 states or utilized as the framework for the state Science Standards in 24 other states (National Science Teaching Association, n.d.-a).

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The prevalence of NGSS in K-12 education and the need to integrate STEM (Science, Technology, Engineering, and Mathematics) into all aspects of students' learning experiences requires improving STEM literacy across K-12 education (Roehrig et al., 2012). Therefore, implementing foundational STEM literacy in children's early education is essential. Elementary classrooms provide exposure to multiple content areas within the school day fostering a greater chance for an interdisciplinary approach to teaching STEM disciplines (Tank et al., 2013). K-2 literacy teachers' time with STEM concepts opens opportunities for literacy learning (i.e., the use and practice of literacy skills) as well as explores new ways of using literacy that are important to highlight how people in STEM fields communicate (Wright & Wenk Gotwals, 2023). Children's books can introduce young children to the concepts of STEM and can "generate interest in a topic, present a problem, challenge misconceptions, and explain content" (Jackson et. al., 2018, p. 4).

Teachers have an active role in supporting STEM literacy through their choices in children's reading resources. In addition, teachers can increase the impact of reading resources through read alouds. The benefits of reading aloud to children are many and include increasing their vocabulary (Beck et al., 2002; De Temple & Snow, 2003) and listening comprehension skills (Morrow & Gambrell, 2002). A case study by Isidro (2021) offered evidence of emerging engineering disciplinary literacy skills in K-2 settings through teacher scaffolding and the use of developmentally appropriate materials and tasks. The effectiveness of reading aloud is improved when teachers implement reading engagement practices such as creating anticipation about the story by discussing its book cover, soliciting and verifying predictions about the story, and making connections to other books or the children's own lives (Acosta-Tello, 2019).

In addition, reading aloud STEM books with diverse perspectives helps in "exposing our youngest learners to appealing, culturally authentic, and scientifically accurate picture books alongside opportunities to embody science practices [and] is a valuable way to promote the formation of science identities and cultural awareness and humility for all students" (Eades-Baird et al., 2022, p. 47). Due to the lack of representation in the breadth of STEM picture books (i.e., parallel populations, gender, disabilities, religion, sexual identity, and socio-economic status), Cardullo and Burton (2022) state that choosing STEM books with diverse perspectives should be intentional to build bridges across cultures, teaching, and learning.

Enhancing young children's STEM knowledge and skills through project-based learning has been found to be successful as well (Duke et al., 2016), and research suggests that reading and writing taught in the context of STEM is better than separating the subjects, even with young learners (Vitale & Romance, 2011).

In conjunction with the aforementioned benefits, engaging K-2 children through read alouds can increase their ability to identify problems and problem solve. NGSS for K-2 children addresses this through engineering design. According to NGSS, the focus of K-2 engineering design is "thinking through the needs or goals that need to be met, and which solutions best meet those needs and goals" (2013, p. 3). A study by Haluschak et al. (2018) shows that K-2 children meaningfully take part in initial problem scoping through engagement with naming, analyzing, and reflecting within the introduction to the problem. The authors define problem scoping as "the need to deeply understand the problem as part of the process of developing solutions" (Haluschak et al., 2018, p. 3). The authors acknowledge that this is a skill that is developed through increased exposure to and experiences with engineering design (Haluschak et al., 2018). Children's books can present explicit and implicit engineering concepts for children to explore.

Haluschak et al. (2018) suggest improving engineering literacy through an active review of the NGSS Science and Engineering Practices and Engineering Design performance expectations, and then to explore their connections to content and activities in their respective classrooms. Next, teachers should assess their classroom literature resources to determine if they are representative of the diverse perspectives of students' lives (i.e., local, state, regional, national, and international). Teachers should continue to read aloud from a meaningfully curated selection of picture books, and this should be employed with proven reading engagement practices. Engineering literacy can then be expanded through students' active participation and critical thinking through problem scoping (Haluschak et al., 2018).

What follows is an annotated bibliography of children's books that present engineering concepts tied to the NGSS Science and Engineering Practices for K-2 students (NSTA, n.d., see Appendix A) and NGSS K-2 Engineering Design performance expectations (NSTA, n.d., see Appendix B). The selected children's books encourage discussion and model the process of inquiry and problem solving that may inspire young children to explore questions of their own from their own perspectives.

Annotated Bibliography

Abe, M. (2020). *Avocado asks, what am I?* Doubleday.

Avocado has a nice life in the grocery store until a young girl asks, "Is an avocado a fruit or a vegetable?" (Abe, 2020). Feeling like it doesn't belong in either group, a series of other questions are asked—"Am I a fish? Am I cheese?" (Abe, 2020). Then Avocado meets Tomato who says she is a fruit also! They celebrate their uniqueness until they are asked questions by a spork saying, "Am I a spoon or a fork?" (Abe, 2020). And a mushroom asks, "Am I a fruit or a fungus?" (Abe, 2020). Questions abound in this fanciful tribute to inquiry.

- ♦ Science and Engineering Practice #1
- ♦ Engineering Design K-2-ETS1-1

Beaty, A. (2016). *Ada Twist, scientist* (D. Roberts, Illus.). Abrams.

A young girl does all the things a baby does except speak. She is curious and finally one day, she says her first word: Why? And the why questions never stopped—from "Why are there pointy things stuck to a rose?" and "Why are there hairs up inside of your nose?" (Beaty, 2016). Once in school, she continues to ask questions about good and bad smells. She has a hypothesis about an unpleasant smell—it was her dad's cabbage stew, and then came her second hypothesis—the cat caused it. She develops a perfume for the cat, makes a mess, and begins writing experiments and formulas on her wall. Her parents decide that she is a scientist and set out to help her answer some of her why questions, as do her classmates at school. This rhyming book is a celebration of inquiry.

- ♦ Science and Engineering Practices #1, 3, 4, 6, & 7
- ♦ Engineering Design K-2-ETS1-1 and K-2-ETS1-3

Beaty, A. (2013). *Rosie Revere, engineer* (D. Roberts, Illus.). Abrams.

In her room, Rosie Revere secretly makes gadgets and gizmos out of things she has collected from the trash, and she hides her creations under her bed until her great-great-aunt Rose comes for a visit. Rose had worked building airplanes a long time ago, and she tells Rosie her greatest wish is to fly herself. So, Rosie works on a flying invention herself until it flies and then falls apart. Discouraged, Rosie finds consolation in Rose who tells her, "Life might have its failures, but this was not it. The only true failure can come if you quit" (Beaty, 2013). So, she continues to try and shows her classmates that trying, even with failures, is part of the engineering process.

- ♦ Science and Engineering Practices #2 and 3
- ♦ Engineering Design K-2-ETS1-2

Derting, K., & Johannes, S. A. (2018). *Cece loves science* (V. Harrison, Illus.). Greenwillow.

Encouraged to think like a scientist, Cece and her friend Isaac investigate this question: Do dogs eat vegetables? They do the experiment on their dog Einstein. First, they observe Einstein's eating habits. They make the following observations:

"He eats, drinks, and sleeps. He loves to eat his kibble. He doesn't like broccoli. He jumps on the table. Doggie treats guarantee 100% participation" (Derting & Johannes, 2018).

They experiment using these variables: carrots, beans, and cucumbers. He eats none. They mix it with his kibble, and he eats only the kibble. They interpret their data: "Eats bacon, ketchup, and kibble. Ignores hidden vegetables. Result—doesn't like veggies—carrots, beans, and cucumbers. (Derting & Johannes, 2018).

They also notice he loves bananas. So, they mix carrots, beans, cucumbers, and bananas in a blender, and he loves the concoction. So, they change their result to: "Einstein does eat vegetables when we mix them with bananas" (Derting & Johannes, 2018).

The science project worksheet that follows could serve as an anchor chart for inquiry and discovery.

<u>Science Project Worksheet</u> (Derting & Johannes, 2018)

Science (zoology—the study of animals)

- – Brainstorm ideas:
- – What is your question?
- – Your test subject:
- – List some fun facts about your subject:
- – What are your observations?
- – Experiment! What variables are you testing?
- – 1st experiment:
- – 2nd experiment:
- – Interpret your data:
- – Result:
- ♦ Science and Engineering Practices #1, 2, 3, 4, & 6
- ♦ Engineering Design K-2-ETS1-1 and K-2-ETS1-2

Derting, K. & Johannes, S. A. (2019). *Cece loves science and adventure* (V. Harrison, Illus.). Greenwillow.

In this follow-up to the first Cece book, Cece and her class go on a camping trip. She first completes a checklist of items to bring along. She also had a list of things to do once they get to their site:

> "Plan your adventure and pack.
> Set up your campsite.

Go on a nature hike with friends.
Make a list of different plants and animals you find.
Make a map of your wilderness route." (Derting & Johannes, 2019)

Using figures and drawings, they put the tent up. They make a map of where they walked for their hike using the pictures they had taken. Then, as clouds roll in, Cece does the math needed when lightning flashes and then when the thunder rumbles. They need to get back to their camp, so they use the map and a timeline to return before the rain starts.

The last page of the book shows their STEM worksheet.

- Science: Counted lightning strikes to figure out how far away the storm was.
- Technology: Made a map from pictures on the camera so we could find our way back to camp.
- Engineering: Built a shelter to keep us dry.
- Math: Used the time stamps on the pictures to calculate how far we were from camp. (Derting & Johannes, 2019)

- ♦ Science and Engineering Practices #2, 3, 4, 5, & 6
- ♦ Engineering Design K-2-ETS1-2 and K-2-ETS1-3

Derting, K., & Johannes, S. R. (2020). *Libby loves science* (J. Murray, Illus.). Greenwillow.

Another book in this series looks at chemistry. Libby loves to cook and learns that cooking is like chemistry in that it involves mixing, pouring, measuring, and stirring. At the school's science booth, they do a Foaming Fountain Experiment, sometimes called "Elephant's Toothpaste" because it looks like toothpaste coming out of a tube, and a Giant Bubbles Experiment with the secret ingredient being light corn syrup. They also do a Fluffy Slime Experiment using boric acid and sodium borate and an Ice Cream Experiment—making ice cream in a baggie with sugar, milk, and vanilla, inside another baggie with rock salt. For the grand finale, Libby does Libby's EPIC Bottle Rocket Experiment using vinegar and baking soda. Like a cooking recipe, each experiment sheet has materials and instructions illustrating chemical reactions.

- ♦ Science and Engineering Practices #2, 3, & 4
- ♦ Engineering Design K-2-ETS1-2 and K-2-ETS1-3

Kamkwamba, W. & Mealer, B. (2012). *The boy who harnessed the wind*. Dial.

William Kamkwamba grew up in Malawi where a severe drought kills most of the maize fields, including those of William's father. William quit school and used the books from a library to see pictures of windmills. Learning that windmills could produce electricity and pump water, William built a windmill with a tractor fan, shock absorber, and the frame of a broken bicycle missing a wheel. For blades, he melted plastic pipes and flattened them. He used a dynamo for a generator. When the wind blew, he created electricity. He was just 14 years old when this occurred. Eventually, he built a "Green Machine" to pump water. This is a true story of a young engineer who persevered and helped his community.

- ♦ Science and Engineering Practices #1, 2, 3, 4, 5, 6, 7, & 8
- ♦ Engineering Design K-2-ETS1-1, K-2-ETS1-2 & K-2-ETS1-3

Larsen, R., & Gibson, B. (2021). *Uma Wimple charts her house*. Anne Schwartz Books.

Uma loves to make charts and graphs of everything from all the trees she passes on her way to school to Wimple family pizza topping preferences. So, when her teacher assigns a chart of our home, Uma is thrilled. The problem is, she has so much information, how will she organize it? Pie charts, bar charts, Venn diagrams, pyramid charts, maps, and tree charts are explained, and examples of each are on the endpapers of the book as the book encourages mapping and charting everything in one's life.

- ♦ Science and Engineering Practices #1, 2, & 4
- ♦ Engineering Design K-2-ETS1-1, K-2-ETS1-2 & K-2-ETS1-3

Paul, M. (2015). *One plastic bag: Isatou Ceesay and the recycling women of the Gambia* (E. Zunon, Illus.). Millbrook Press.

This story of how one woman, Isatou Ceesay from Njau, helped to cut down on the number of plastic bags used in Gambia. Noting the need for a sturdy bag to carry things in and noticing the plethora of plastic bags in the garbage, she enlists the help of women who knew how to crotchet to start using plastic strips made from the plastic bags to make and sell crotched plastic bags that are both durable and sustainable. This movement has continued, and the impact on the area near Njau has been dramatic as this solution to a problem has had a ripple effect on the women's health, income, and self-confidence. The women of Njau have contributed some of their earnings toward an empowerment center where community members can attend free health and literacy classes; the center is also the home for the region's first public library.

- Science and Engineering Practices #1, 2, 3, 4, 5, 6, 7, & 8
- Engineering Design K-2-ETS1-1, K-2-ETS1-2 & K-2-ETS1-3

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

A young girl decides to make the most magnificent thing from scraps and supplies she has collected. Nothing quite works, so she walks away in disgust, despair, and disappointment. Eventually, she returns to her work as passers-by offer suggestions. Finally, she has made a scooter with a sidecar for her dog. It isn't perfect, but it works. "The pair take a good, long look. It leans a little to the left, and it is a bit heavier than expected. The color could use a bit of work, too. But it is just what she wanted" (Spires, 2014). Persistence pays off in this book celebrating trial and error.

- Science and Engineering Practices #2 and 6
- Engineering Design K-2-ETS1-2

Tanco, M. (2019). *Count on me*. Tundra.

A young girl shares that her passion is math. She includes a math notebook at the end of the book to show what she dreams about and is passionate about. Included in the notebook are pictures and models of fractals, basic polygons, concentric circles, types of curves, solid figures, types of trajectories, and kinds of sets. Math passion and application are encouraged throughout the book.

- Science and Engineering Practice #5
- Engineering Design K-2-ETS1-2

Van Dusen, C. (2019). *If I built a school*. Dial.

Jack tells his teacher that if he built a school, he would include tubes made of glass, free floating platforms, hover desks, hologram guests, trampoline basketball courts, rock walls, skydiving wind tunnels, etc. The endpapers of this book are diagrams and blueprints of various school shapes and construction in this exhibition of creativity.

Van Dusen has several other similar books to this one, namely:
Van Dusen, C. (2005) *If I built a car*. Dial.
Van Dusen, C. (2012) *If I built a house*. Dial.

- Science and Engineering Practices #1, 2, & 3
- Engineering Design K-2-ETS1-1 and K-2-ETS1-2

Winter, J. (2008). *Wangari's trees of peace: A true story from Africa*. Orlando.

This is the true story of how one woman helped her country by planting trees. Wangari Maathai left her native Kenya to attend college in America, and when she returned to Kenya, she found barren ground, as well as poor soil, erosion, and a lack of clean drinking water in rural areas. Looking to solve a problem in her native country, she started the Green Belt Movement in Kenya in 1977 on World Environment Day by planting nine seedlings in her own backyard. She enlisted the help of many women, and by 2004, thirty million trees had been planted. She was awarded the 2004 Novel Peace Prize. Solving real community problems is featured in this tribute to Wangari Maathai.

- Science and Engineering Practices #1, 2, 3, 4, 5, 6, 7, & 8
- Engineering Design K-2-ETS1-1, K-2-ETS1-2 & K-2-ETS1-3

Conclusion

These books encourage and embody science and engineering practices in celebration of inquiry and problem solving. They can inspire and educate even our youngest budding scientists and engineers as they integrate reading and writing taught within the context of STEM concepts. Books tied to real world experiences help students relate STEM and reading to their own lives and reinforce those important skills of inquiry learning and problem solving.

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Appendix A

<u>Next Generation Science Standards – Science and Engineering Practices</u>

1. Asking Questions and Defining Problems

A practice of science is to ask and refine questions that lead to descriptions and explanations of how the natural and designed world(s) works and which can be empirically tested. Engineering questions clarify problems to determine criteria for successful solutions and identify constraints to solve problems about the designed world. Both scientists and engineers also ask questions to clarify ideas.

K-2 Condensed Practices: Asking questions and defining problems in K-2 builds on prior experiences and progresses to simple descriptive questions that can be tested.

2. Developing and Using Models

A practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas, mathematical representations, analogies, and computer simulations. Modeling tools are used to develop questions, predictions, and explanations; analyze and identify flaws in systems; and communicate ideas. Models are used to build and revise scientific explanations and proposed engineered systems. Measurements and observations are used to revise models and designs.

K-2 Condensed Practices: Modeling in K-2 builds on prior experiences and progresses to include using and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions.

3. Planning and Carrying Out Investigations

Scientists and engineers plan and carry out investigations in the field or laboratory, working collaboratively as well as individually. Their investigations are systematic and require clarifying what counts as data and identifying variables or parameters. Engineering investigations identify the effectiveness, efficiency, and durability of designs under different conditions.

K-2 Condensed Practices: Planning and carrying out investigations to answer questions or test solutions to problems in K-2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions.

4. Analyzing and Interpreting Data

Scientific investigations produce data that must be analyzed in order to derive meaning. Because data patterns and trends are not always obvious, scientists use a range of tools—including tabulation, graphical interpretation, visualization, and statistical analysis—to identify the significant features and patterns in the data. Scientists identify sources of error in the investigations and calculate the degree of certainty in the results. Modern technology makes the collection of large data sets much easier, providing secondary sources for analysis. Engineering investigations include analysis of data collected in the tests of designs. This allows comparison of different solutions and determines how well each meets specific design criteria—that is, which design best solves the problem within given constraints. Like scientists, engineers require a range of tools to identify patterns within data and interpret the results. Advances in science make analysis of proposed solutions more efficient and effective.

K-2 Condensed Practices: Analyzing data in K-2 builds on prior experiences and progresses to collecting, recording, and sharing observations.

5. Using Mathematics and Computational Thinking

In both science and engineering, mathematics and computation are fundamental tools for representing physical variables and their relationships. They are used for a range of tasks such as constructing simulations; solving equations exactly or approximately; and recognizing, expressing, and applying quantitative relationships. Mathematical and computational approaches enable scientists and engineers to predict the behavior of systems and test the validity of such predictions.

K-2 Condensed Practices: Mathematical and computational thinking in K-2 builds on prior experience and progresses to recognizing that mathematics can be used to describe the natural and designed world(s).

6. Constructing Explanations and Designing Solutions

The end-products of science are explanations, and the end-products of engineering are solutions. The goal of science is the construction of theories that provide explanatory accounts of the world. A theory becomes accepted when it has multiple lines of empirical evidence and greater explanatory power of phenomena than previous theories. The goal of engineering design is to find a systematic solution to problems that is based on scientific knowledge and models of the material world. Each proposed solution results from a process of balancing competing criteria of desired functions, technical feasibility, cost, safety, aesthetics, and compliance with legal requirements. The optimal choice depends on how well the proposed solutions meet criteria and constraints.

K-2 Condensed Practices: Constructing explanations and designing solutions in K-2 builds on prior experiences and progresses to the use of evidence and ideas in constructing evidence-based accounts of natural phenomena and designing solutions.

7. Engaging in Argument from Evidence

Argumentation is the process by which evidence-based conclusions and solutions are reached. In science and engineering, reasoning and argument based on evidence are essential to identifying the best explanation for a natural phenomenon or the best solution to a design problem. Scientists and engineers use argumentation to listen to, compare, and evaluate competing ideas and methods based on merits. Scientists and engineers engage in argumentation when investigating a phenomenon, testing a design solution, resolving questions about measurements, building data models, and using evidence to evaluate claims.

K-2 Condensed Practices: Engaging in argument from evidence in K-2 builds on prior experiences and progresses to comparing ideas and representations about the natural and designed world(s).

8. Obtaining, Evaluating, and Communicating Information

Scientists and engineers must be able to communicate clearly and persuasively the ideas and methods they generate. Critiquing and communicating ideas individually and in groups is a critical professional activity. Communicating information and ideas can be done in multiple ways: using tables, diagrams, graphs, models, and equations as well as orally, in writing, and through extended discussions. Scientists and engineers employ multiple sources to obtain information that is used to evaluate the merit and validity of claims, methods, and designs.

K-2 Condensed Practices: Obtaining, evaluating, and communicating information in K-2 builds on prior experiences and uses observations and texts to communicate new information.

(National Science Teaching Association, n.d.-b)

Appendix B

<u>K-2 Engineering Design</u>

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.

K-2-ETS1-3. Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.

(National Science Teaching Association, n.d.-c)

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ADD YOUR JOURNALS:	Print & Online	Online Only
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