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The best engineering picture books to help elementary teachers and young readers develop an engineering mindset in the classroom (Fundamental)

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Introduction: In many school districts across the United States, elementary science teachers are required to teach engineering practices along with their science units. Unfortunately, engineering K-5 pedagogical methods are not a focus of teacher development and the number of college level preservice programs that teach engineering teaching strategies are few and far in between. Frameworks have been developed for secondary education and teaching resources written by educational companies are available for elementary teachers, but wide consensus does not exist on the best practices for teaching engineering practices. While opportunities exist for K-5 educators to attend engineering national conferences and professional development workshops, there is still a well-documented need of improving teacher self-efficacy for engineering education. One strategy that works is anchoring lessons in familiar instructional routines such as incorporating engineering context in science and ELA readings, eliciting *engineering talk* after design activities, and incorporating children's literature as a springboard for design challenges. In this study, the Best STEM Book Awards lists 2017-2025, a joint project of the American Society for Engineering Education, the International Technology and Engineering Educators Association, the National Science Teaching Association, the Society of Elementary Presidential Awardees, and the Children's Book Council, were analyzed to determine which criteria constituted an engineering picture book. Using a conventional content analysis approach, engineering themes were identified in the recommended books for teachers and a codebook with themes related to an identity in-practice framework emerged to curate a specific list of K-5 engineering picture books teachers should use to teach the engineering habits of mind, the engineering design process, and career exposure.

Literature Review: It was the consensus of the National Research Council's (NRC) *A Framework for K-12 Science Education* that made engineering a disciplinary core idea of science education. Since 2011, almost all states have rewritten their educational science standards that are influenced by the *Framework* including 20 states which directly adopted the Next Generation Science Standards [1]. This shift represents a significant change for elementary educators, who are now integrating engineering content and practices into their science classrooms. Unfortunately, support for doing so remains limited. While there are standards and frameworks that can be implemented across all grade levels such as NGSS, Standards for Technological and Engineering Literacy (STEL ITEEA) and the Framework for P-12 Engineering Learning [2], there is little formal engineering preparation for preservice teachers before entering the field. Consequently, many elementary educators enter the classroom with low self-efficacy in engineering pedagogy [3]. These challenges are pronounced in elementary settings where teachers are responsible for teaching across multiple content areas every day.

Rather than asking educators to adopt new instructional approaches, teachers should build on pedagogies they use every day. Picture books are a well-established instructional tool in elementary classrooms and serve as a powerful method for introducing content to students, bridging the gap between teachers' self-efficacy in teaching about engineering [4]. High quality picture books draw from real life scenarios, social issues, and problems that children can relate to, supporting better understanding of new concepts, and can be used as impactful instructional tools within and beyond the curriculum [5]. By leveraging resources teachers already use and trust, engineering can be embedded into existing routines. Integrated literacy approaches highlight that teaching reading with hands-on explorations and meaningful discussion strengthens disciplinary learning and literacy development [6].

These practices naturally lend themselves to engineering learning. In this study we were interested in examining high quality engineering picture books and understanding how they support the communication of engineering content and practices. We focused on books that were published in the Best STEM Book Awards lists, which have already been reviewed and selected through an annual review by a panel of experts. Their criteria include books that model real world problem solving and authentic design while highlighting key engineering habits of mind such as systems thinking, creativity, collaboration, and persistence. The criteria also include the representation of the iterative process of engineering, looking for clear examples of trial and error, redesign, and improvement over time. Based on this curated collection, we narrowed our analysis to books with a clear engineering focus to better understand the ideas they present.

This focus on engineering picture books is further supported by the growing body of research that suggests that engineering learning is developmentally appropriate in early childhood. At an early age, children are capable of engaging in engineering practices such as problem identification, design, and testing. These interactions often occur through play-based activities and hands-on experiences [7]. Studies of early engineering learning suggest that these experiences occur naturally in children's everyday lives, with block building, construction play, family prompted questions, and problem-solving at home. Parents often support early engineering informally by encouraging tinkering, building, and experimentation. Even if they do not realize it, they are engaging their children in engineering practices [8].

Engineering can be taught effectively in the classroom by engaging K-5 students in the engineering design process, engineering habits of mind and providing opportunities for career exposure. The engineering design process (EDP) provides an accessible structure for teachers to introduce engineering to elementary students. Models with the steps of Ask, Imagine, Plan, Create, Test, and Improve emphasize that engineering is iterative and creative rather than linear [9]. This process encourages students to revisit ideas, learn from failure, and refine solutions, reflecting authentic engineering practices. Young learners can engage in this kind of iterative *try and try again* problem solving when design tasks are scaffolded with clear goals, opportunities to test, and teacher prompts to push students to explain and revise their ideas [10].

Students must also learn how engineers think and mirror those processes. Engineering habits of mind describe the dispositions that engineers use when approaching problems, including creativity, persistence, optimism, collaboration, systems thinking, and resilience [11]. In the United States, these habits were articulated by the National Academy of Engineering & NRC as part of the effort to define developmentally appropriate goals for K-12 engineering education. In the United Kingdom, the Royal Academy of Engineering developed a similar framework on ways of thinking but places greater emphasis on action-oriented habits and the integration of design practices that align with the engineering design process [12]. The labels and structures of the frameworks differ, but both highlight the importance of helping students develop these engineering dispositions that support perseverance, creativity, collaboration, and thoughtful decision making. Developing these habits in elementary school not only supports engineering learning but also aligns with social-emotional and character education goals already valued in K-5 classrooms [10].

Career exposure is also a critical component of early engineering education as many young children form limited or inaccurate concepts of what engineers actually do [13]. Without intentional exposure, these misconceptions can limit student interest and aspirations. When students encounter representations of engineers who resemble themselves and address problems that matter in their communities, an engineering career becomes more accessible and relevant.

These representations support early career awareness and contribute to the development of engineering identities while understanding the broader impact of engineering on people and society [2].

To use picture books effectively as a teaching strategy, it was first necessary to identify what engineering concepts, practices, and ways of thinking are embedded within the texts and if they align with the literature about what elementary students should learn about engineering. The purpose of this study was to examine high quality STEM picture books to understand how engineering is represented within children's literature. This study was guided by two research questions:

RQ 1: What are the engineering concepts depicted in high quality STEM picture books?
RQ 2: How can elementary teachers use these books to support student learning about engineering?

Methods: A conventional content analysis approach was used to examine themes present across the recommended children's books. This approach allowed the authors to interpret textual and visual data on every page to identify patterns and representations of engineering ideas [14]. The analysis led to the development of a codebook that could capture the representation of engineering in each book while also informing the structure of pedagogical tools for K-5 teachers to use, including an educator rubric and guiding questions.

A database of 222 children’s books published between 2017 and 2025 was created based on the Best STEM Book Awards lists. This annual list highlights exemplary STEM books - different from recommended science trade books - which through expert review emphasize real-world problem solving, interdisciplinary thinking, and realistic representations of STEM practices. The Best STEM Book Awards lists are popular among science teachers as they serve as a trusted source of high-quality books for supporting STEM learning. Books were identified by grade level and tagged in the database by their most prevalent discipline (math, science, engineering, technology) based on Best STEM Book Awards reviewer summaries. The first filters were used to eliminate books above the K-5 grade levels as well as chapter books, non-fiction books, and activity guides. This resulted in 108 books. From this subset, the tags were used to remove science or mathematics books, without an engineering emphasis. Application of these filters resulted in a final sample of 44 engineering themed picture books selected for full analysis (Figure 1).

To capture the engineering ideas in the books, we followed established content analysis methods similar to those used for picture books about autism [15] and underrepresentation in engineering [16]. The authors independently read five books, first holistically examining the pictures on each page and then closely reading the text. During these two phases, engineering related ideas were recorded in a coding journal, documenting recurring patterns, action, language, and visual representations of engineering. Snippets of text and phrases describing the visuals were collected in a spreadsheet for each book [17]. Patterns were identified across all five books and through

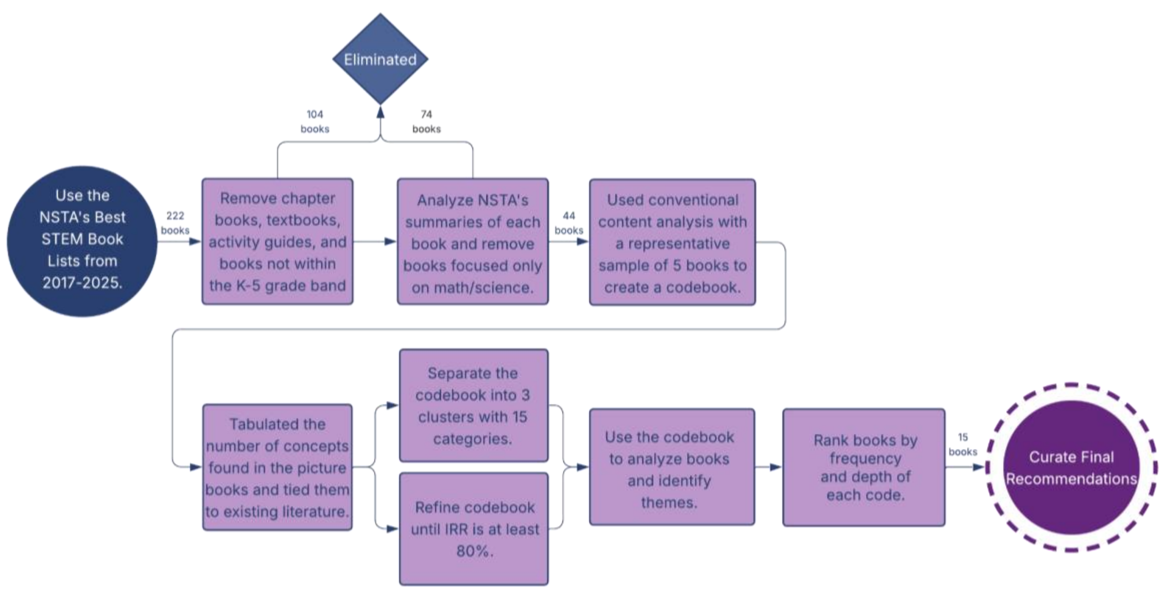

Figure 1: Flowchart describing the methods to identify the final children's engineering picture books.

multiple rounds of discussions, an emergent list of codes was developed. Some of the codes included problem, solution, iteration, collaboration, ethical consideration, optimism, creativity, and career. Next, those codes were organized into larger conceptual categories. Language from the coding journals was used to guide this process, ensuring that categories were grounded in the text and picture descriptions. A pattern emerged during the content analysis that related to the K-5 engineering education literature. It resulted in three overarching clusters: engineering design process [18, 19], engineering habits of mind [20, 21, 22, 23] and career exposure [24].

With the established clusters, the authors reviewed the same five books together and deduced new codes that aligned with each cluster focusing mainly on EDP and Habits of Mind. The authors defined each one, established inclusion and exclusion criteria, and included a representative book quote for each code. For example, the analysis made a distinction between problem finding and problem scoping, but both codes were related to the cluster of EDP and the category of Ask, Imagine, & Plan (Table 1). The authors then reviewed five more books calculating inter-rater reliability (IRR) after each one. After 14 coding rounds and regular revisions to the codebook, an IRR of at least 80% was reached across five consecutive coding rounds [17]. At this point the team split the total number of books in half and coded them independently. Coding results were compiled into a spreadsheet to examine the code frequency per page per book.

Results: The final codebook was organized into 3 clusters, 8 categories and 15 unique codes (Table 2). Since these books were written for a K-5 audience it was appropriate to define the EDP as a three-step design process through the categories of Ask, Imagine, & Plan (Define), Create, and Improve, which encapsulate six distinct steps in the books: Problem Finding, Problem Scoping, Prototyping, Solution, Testing, and Iteration.

The cluster for engineering habits of mind was based on evidence in the books that demonstrated ways of thinking about problems and solutions. While the engineering education literature aligns with either the Royal Academy of Engineering EHoM characteristics or the NAE Habits of Mind, the children's picture books analyzed in this study do not seem to prescribe to either one. Rather, the dispositions most coded in the books were empathy, ethical considerations, systems thinking, collaboration, optimism, resilience, creativity, and curiosity. Career exposure was also

Table 1: Under the EDP cluster, the first category was Ask, Imagine, & Plan which is divided into two codes: problem finding and problem scoping. The definition and inclusion criteria were the result of multiple rounds of refinement.

Category	Code	Definition	Includes	Excludes	Examples
Ask, Imagine, & Plan	**Problem-finding**	Description of a challenge or need that can be improved or solved using the Engineering Design Process.	Identifying problems, observing issues, defining a need	Solutions without identifying the problem first	Toucans' beak broke and needed to be fixed to live (Building a Beak)
	Problem-scoping	Exploring a problem and considering the processes that aid in finding a solution.	Ideation, brainstorming, planning, sketching, gathering materials, constraints, setting goals, setting criteria	Prototyping, iteration, problem, and solution (later steps of EDP)	"Bear's job will be to focus on planning, staying organized, communicating coordinating, scheduling" (Bear Builds a House)

Table 2: The content analysis resulted in a codebook with 3 clusters, 8 categories and 15 unique codes:

Cluster	Category	Code
Engineering Design Process	Ask, Imagine & Plan	Problem-finding
		Problem-scoping
	Create	Prototyping
		Solution
	Improve	Testing
		Iteration
Career Exposure	Career Exposure	Career

Cluster	Category	Code
Engineering Habits of Mind	Conscientiousness	Empathy
		Ethical Consideration
	Systems Thinking	Systems Thinking
	Collaboration	Collaboration
	Engineering Attitudes	Optimism
		Resilience
		Creativity
		Curiosity

a common code found in many of the books but did not fit with the other two clusters. The authors kept it as a separate category and cluster as children's literature typically shows representation of individuals in careers not historically accessible by everyone [19].

Once all the engineering picture books were coded, the authors were able to group books into clusters based on the average instances of codes found per page. A z-score was calculated for each book which demonstrated that some books aligned more strongly with one cluster relative to another (Table 3). For example, our analysis found that *Lion Lights* and *Karl's New Beak* represented more themes (z = 1.891 and z =1.454) about the engineering design process than habits of mind and career objectives. In terms of career exposure, *Someone Builds the Dream* and *Bear Builds a House* contained more references to jobs (z = 3.266 and z =1.861) as the main characters had to work together to build structures in the world or literally build a house, respectively. Moreover, some of the books like *Izzy Gizmo* and *The Most Magnificent Thing* demonstrated substantial representation in at least two of the three clusters, reinforcing the interconnected nature of engineering design and the habits of mind.

Table 3: A representative sample of book z-scores for each cluster

Book Titles	EDP*	HoM**	Career
Lion Lights: My invention that made peace with lions	1.891	-0.213	0.131
Karl's New Beak: 3D Printing builds a bird a better life	1.454	-0.994	-0.229
Green City: How one community survived a tornado and rebuilt for a sustainable future	-1.068	1.974	0.612
Whoosh!: Lonnie Johnson's Super Soaking Stream of Inventions	0.306	1.593	0.221
Someone Builds the Dream	-0.831	-1.199	3.266
Bear Builds a House	0.448	0.451	1.861
Izzy Gizmo	1.386	1.644	-0.622
The Most Magnificent Thing	1.395	1.636	-0.950

n = 44 books, * EDP = Engineering Design Process, ** HoM = Engineering Habits of Mind

Educator Rubric: The final version of the codebook also helped in designing an educator rubric as a resource to support teachers in identifying engineering themed picture books on their own. Rather than requiring educators to purchase the recommended specific titles, the rubric enables educators to use picture books already available in their classrooms or school libraries. The rubric was developed from the same clusters and codes in the final codebook. To support accessibility and classroom use, the technical language of the codebook was translated into yes/no questions with code definitions restructured as prompts teachers could ask themselves while evaluating a book for a lesson. For example, under the cluster Engineering Design Process/Ask, Imagine, & Plan, the definition for the code *problem finding*: was turned into a question - Is there a clear problem that the character can address using the Engineering Design Process? As a result, the rubric is educator-friendly, remaining usable without specialized training in engineering education. Teachers can use the rubric to evaluate whether a book introduced a given engineering topic by asking themselves the prompts. If a book receives three or more yes responses out of five in a category, it can be considered suitable for introducing that specific engineering concept, when the teacher centers discussion and instruction aligned to the rubric questions. The full educator rubric is available in an accompanying PCEE 2026 Resource Exchange article to support direct classroom implementation and teacher use.

The top three books that scored highest in each category were also reviewed further to develop book specific guiding questions that allow teachers to take the instruction beyond the text and engage students in discussion that directly targets an engineering concept. The guiding questions were developed by intentionally combining the codebook and the educator rubric, ensuring alignment between research findings and realistic classroom use. In addition to book specific questions, a set of general guiding questions was developed for each of the three themes, allowing teachers to apply the same analytic lens to any high-quality engineering picture book. These can be found in a recently published *Science and Children* article.

Discussion: This work investigated the themes present in popular children's engineering picture books and how K-5 science educators can integrate them in their classroom to teach engineering concepts. There are three powerful themes that were apparent and can be used to further engineering identity exploration. This includes engineering career exposure, engineering pedagogy through the instruction and application of the engineering design process, and engineering habits of mind which captures the ways of thinking and solving problems.

Broadly, career exposure emerged in the analyzed books, not by presenting engineering as a technical field reserved for experts, but as a set of skill sets to accomplish project tasks. The skills can be practiced by anyone which disrupts the stereotypical image of engineering as highly specialized and theoretical. At the K-5 level, this makes engineering skill sets accessible and allows elementary students to "try-on" engineering roles, experimenting with behaviors, and broadening their view of possible careers.

For example, *Blast Off!: Mary Sherman Morgan Fueled America into Space* depicts engineering through real world problem solving emphasizing the thinking and practices behind Mary Sherman's work as an aerospace engineer. Likewise in *Up Periscope!: How Engineer Raye Montague Revolutionized Shipbuilding* the author provides a clear example of career exposure highlighting naval engineering and computer aided engineering while simultaneously showing how *Raye* used mathematics, systems thinking, and computer programming to redesign how ships were built. The story highlights how *Raye* solves, preserves, and succeeds in her career as an engineer. When picture books show relatable, diverse characters solving problems and redesigning ideas, children are more likely to see engineering as something they can do and to start conceptualizing an engineering identity [25, 26].

The engineering ways of thinking about problems were very prominent across the literature. This study drew from both the U.S. and the U.K frameworks for engineering habits of mind. It combined the U.S. framework that emphasizes dispositions such as creativity, persistence, and systems thinking and paired it with the U.K framework which places greater emphasis on action-oriented ways of thinking connected to design and making, like improving, creative problem solving, and curiosity. The codebook developed in this study used both perspectives as codes from the storylines were not prescriptive to either framework. In many instances, the action-oriented ways of thinking were more closely related to the engineering design process cluster and the dispositions aligning more with the engineering habits of mind cluster.

The storylines in the books were found to be well suited for teaching engineering habits of mind because the characters, dialogue, decisions, and actions connect to K-5 students. Through an accompanying design challenge, students would be able to mirror the dispositions of creativity, collaboration, and perseverance through problem solving moments. The habits are embedded in the literature through narratives and illustrations. For example, in *Izzy Gizmo,* the habits of mind are central to the storyline of Izzy trying to help an injured crow build new wings to fly again by trying unconventional solutions. She encounters failure and persists through redesign and testing, modeling how engineers respond to setbacks. Teachers can use these moments to name and reinforce these habits of mind during the read-aloud and following activities supporting their students to think and act like engineers.

The engineering design process was another dominant theme across the analyzed books, though it was not always represented evenly across all the phases. This study aligned the steps of the

EDP steps with the five step YES Elementary Engineering Design Process [13], allowing for a clear separation between problem scoping, prototyping, and iteration phases. This enabled the researchers to quantify what steps of the design process the books described.

In *Building a Beak*, the author devotes a large part of the narrative to problem finding and problem scoping for the toucan's broken beak. The engineers work to prototype and solve the problem with a new 3D printed beak which allows the toucan to return to its natural habitat. Reading about the engineering design process through picture books offers elementary students an entry point into engineering thinking. By showing engineering as iterative, creative, and grounded in problem-solving these stories help students understand how engineers approach challenges.

These findings show that high quality engineering picture books effectively support elementary students' understanding of engineering as both a set of practices, a possible career and a way of thinking. By embedding these ideas in familiar teaching routines, picture books offer educators an accessible and instructionally meaningful way to help students think and act like engineers while building early engineering identities.

Limitations: There are some limitations to the presented study including the subset of books analyzed. Engineering themed children's books are numerous and they are published in many countries. Various libraries and engineering organizations publish lists of recommended children's books. This study only focused on a subset of the picture books from the Best STEM Book Awards lists, but this is because many science teachers are already using them in their classrooms and picture books are appropriate for K-5 as a springboard for design challenges and discussions about engineering ways of thinking. A second limitation is that the career exposure cluster could have further been developed into other categories that encompass well established sociological career theories. We leave that as a goal of a follow up study.

Conclusions: A content analysis of engineering themed picture books from Best STEM Book Awards lists 2017 - 2025 revealed that the themes found in the written text and their accompanying illustrations depict storylines where engineering practices, ways of thinking, and career knowledge are valuable to solving problems. These depictions seem to align closely to the steps of the engineering design process, the engineering habits of mind, and career trajectories. The variation in how well the 44 books addressed each of the engineering categories shows that some of the STEM books will be better for instruction than others. The frequency of codes per page demonstrates that some of the books are suited to describe the engineering mindset while others address the practices engineers use to solve problems. Career exposure was less present in this sample of books, which could be partly attributed to the target audience, but when it was the main theme, it gave a variety of possible tasks that were necessary to accomplish large scale projects. The picture books that were qualitatively ranked highest by the authors also correlated to the books with the highest z-scores related to the clusters of the design process and the habits of mind.

The themes present in engineering picture books can be particularly useful for elementary science teachers who are expected to incorporate engineering topics in their lessons. Instead of requiring additional teaching credentials, K-5 educators should feel confident in applying their pedagogical expertise to use high quality picture books as a vehicle to integrate engineering topics in their classroom. With the research informed educator rubric, teachers can select books that cater to the three engineering clusters and develop design challenges from the storylines.