

Family STEM Learning:

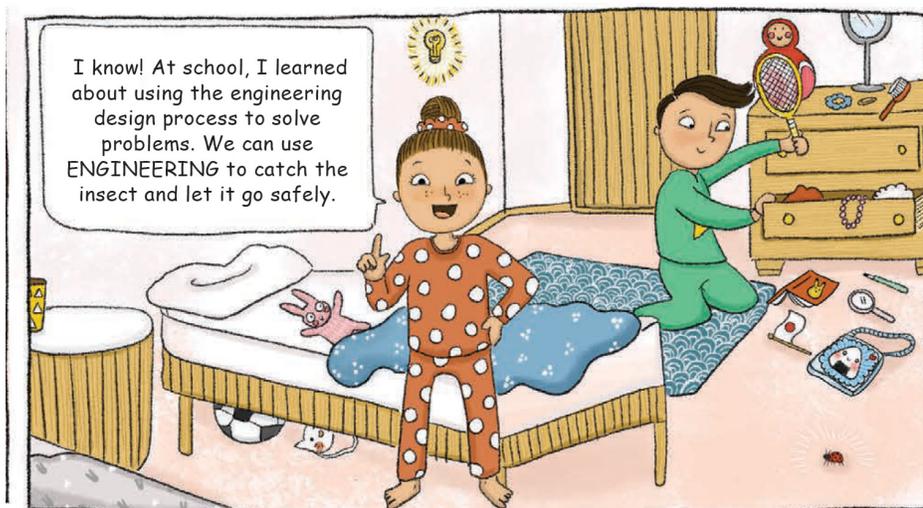
Resources to Inspire Interest and Engagement

By Chris San Antonio-Tunis, Christine A. Gentry, and Jeremy C. Simon

It's hard to overstate the pressures that classroom educators are dealing with in this moment. For years, K-12 educators have adapted their practice as standards change and new subjects come to the fore. They have become experts at using their limited instructional minutes in the most efficient ways possible. Now, as we close out our third year of the COVID-19 pandemic, educators face the added challenge of bridging a pervasive achievement gap that has left large numbers of students scoring below grade level across subject areas (National Assessment of Educational Progress, 2022). To complicate matters, the students

hit hardest by pandemic-related learning loss tend to be from high poverty communities where schools and teaching staff are already under-resourced (US Government Accountability Office, 2022). For better or worse, educators are accustomed to doing more with less, and many are reaching for low-cost curricular materials to re-engage their students, inspire interest, and promote learning. Below, the authors explore a new program from EiE® and the Museum of Science, Boston, designed with these pressures in mind. The EiE Families® program aims to increase student understanding of engineering and computer science by making research-based STEM activities freely accessible to families.

The benefits of family learning are well-documented. Dr. Joyce Epstein, Director of the



Center on School, Family, and Community Partnerships, and Professor of Education at Johns Hopkins University notes that family learning provides valuable opportunities for students to gain skills while fostering self-efficacy. Further, she notes that family learning promotes positive regard between educators and caregivers and allows parents to see their children as capable learners (Epstein et al., 2018). Research also points to increased student attendance, reduced disciplinary rates, and higher graduation rates as family involvement in their child's learning increases (Henderson & Mapp, 2002). Practically speaking, learning in the out-of-school time (OST) environment can also relieve some of the pressure on classroom educators who are tasked with addressing multiple content areas with limited instructional minutes. Of course, these benefits are all moot unless the learning activities are both engaging and accessible across a broad range of families.

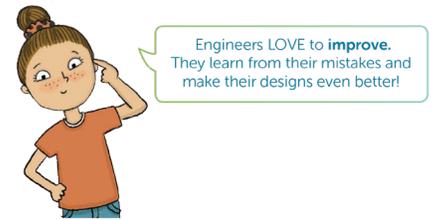
EiE Families builds on two decades of curriculum development experience, both for in-school and OST settings. EiE's flagship in-school curriculum, *Engineering is Elementary*, engages learners in Grades 1-5 with an illustrated storybook that sets

the context for a hands-on engineering design challenge. In 2019, EiE published the results of an NSF-funded study, which found that *Engineering is Elementary* was more effective than a comparison curriculum at improving student understanding of science and engineering (Cunningham et al., 2019). These results were consistent across student demographics suggesting that the EiE approach may be effective at narrowing the STEM achievement gap. The same pedagogical approach was used to create EiE Families, which launched in 2020 and is intended for families with children ages 4-11.

EiE Families uses an illustrated comic to engage children and set the context for a hands-on engineering or computer science challenge. The activities can be done using simple materials found in the home, removing the barrier of an expensive materials kit. To make them broadly accessible, the activity books can be downloaded for free from families.eie.org, or families can

interact with a digital version of the activities through the same website. To appeal to a broad range of families, the characters in the context-setting comic change with each activity book and represent different cultural backgrounds. Importantly, the comics have been illustrated by artists who come from the cultures being represented, providing authenticity and cultural accuracy. All six activity books are available in English and Spanish.

In *Bye Bye Bug*, siblings Kenji and Emi find a ladybug in their bedroom and decide to use their knowledge of engineering to design a way to remove it without harming it. After the problem is introduced, the characters progress through a five-step engineering design process (*Ask, Imagine, Plan, Create, and Improve*), describing each step as they proceed so that families doing the activity can learn about the steps that engineers use to solve problems.



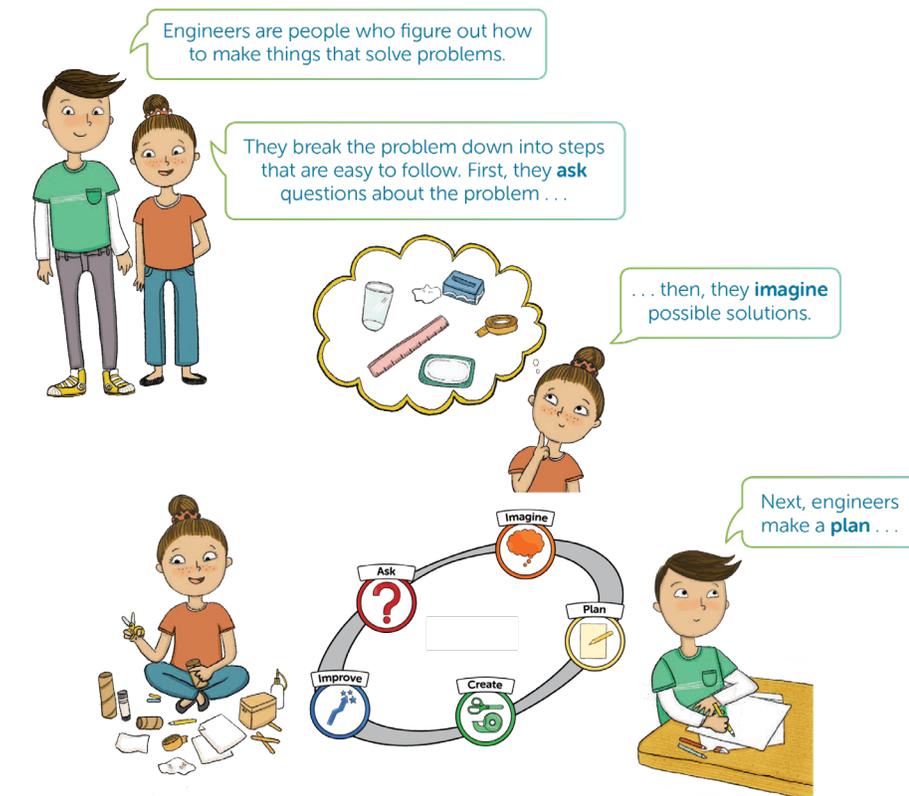
Kenji and Emi eventually design a solution to their problem, but their design is not revealed to the families doing the activity. Instead, families are encouraged to design their own solutions. The open-ended nature of the EiE Families activities is a departure from many common STEM activities, which have prescriptive solutions. Research suggests that activities that provide students with choices about how to achieve success tend to foster greater engagement, self-efficacy, and autonomy (Järvinen & Twyford, 2000).

After testing their design, Kenji and Emi prompt families to think about whether their design solved the problem, and if not, they are encouraged to improve their design and test again. Emi exclaims:

"Engineers LOVE to improve. They learn from their mistakes and make their designs even better!"

This focus on improvement gives families a chance to make their design more effective, which will likely be more satisfying, but it also destigmatizes failure, which will help children begin to value it for what it can teach them. Each activity book ends with suggestions for how families can extend the activity and continue learning together.

During the spring of 2021, the EiE Research & Evaluation team conducted a non-experimental evaluation of *Bye Bye Bug* along with another EiE Families activity called *Keep it Watered*. The purpose of the evaluation was to determine the extent to which these activities were accomplishing the primary goal of the program: to increase child and family understanding of engineering as



a discipline. The team emailed nearly 1,300 families who had previously indicated an interest in testing the activities. Of these, 410 families responded and were sent both activities along with a link to an online survey, which used a retrospective pre-post format. Seventy-five families chose to complete one or both activities and the survey. Participating families were spread

out across 30 states, were predominantly white (73%), female (59%), and skewed suburban (67%), with 24% rural and 9% urban. Participants included 85 adults and 144 children ages 3-14.

Surprisingly, even though families were only incentivized to try one activity, more than half (55%) chose to try both activities, sug-

gesting families found the activities interesting and engaging. Whether families chose to try one or both activities, their responses suggest that the activities improved their understanding of what engineers do (Figure 1). The activities also seem to improve child confidence in their ability to engineer and caregiver confidence in their ability to discuss engineering with their children. Both of these findings suggest the activities improve the likelihood that children will pursue engineering activities in the future and that caregivers may feel less inhibited about having conversations and being actively involved in their child's education even if the subject matter feels unfamiliar (Eccles & Wigfield, 2020).

"I underestimated my kids' engineering skills. I would have never imagined they would come up with the things they did. Very eye opening." -- Caregiver, San Jose, CA

"Engaging problems! I love how open-ended the activity is. Two kids took it in completely different directions." -- Caregiver, Wichita, KS

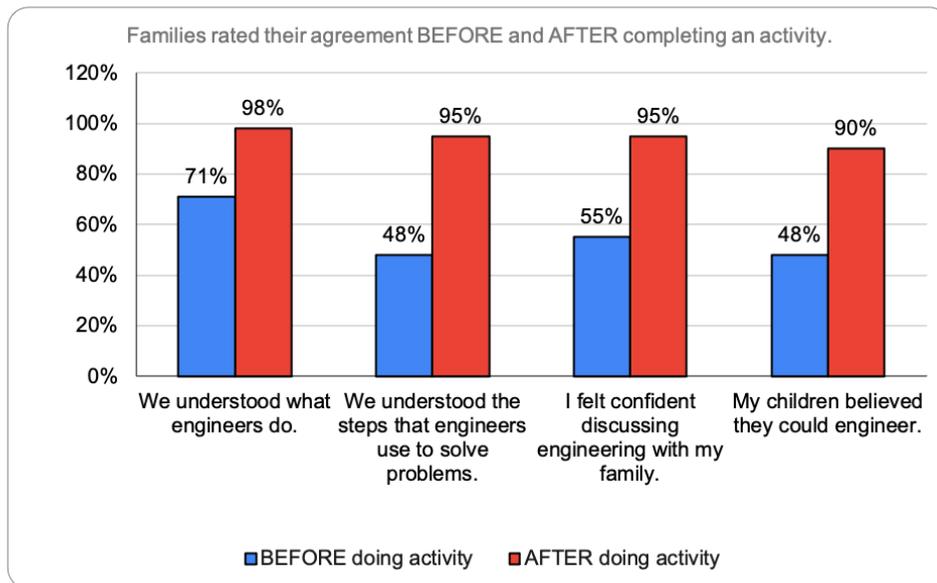


Figure 1.

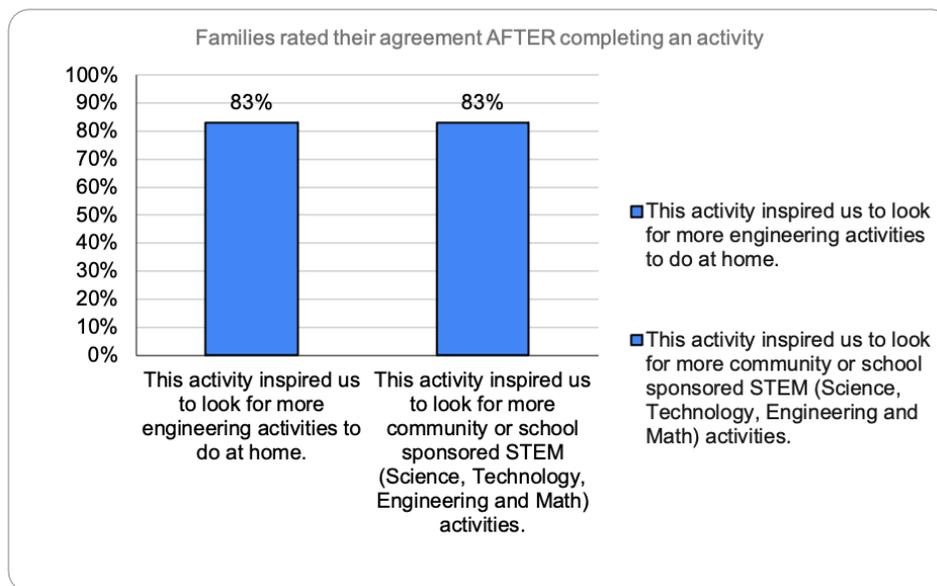
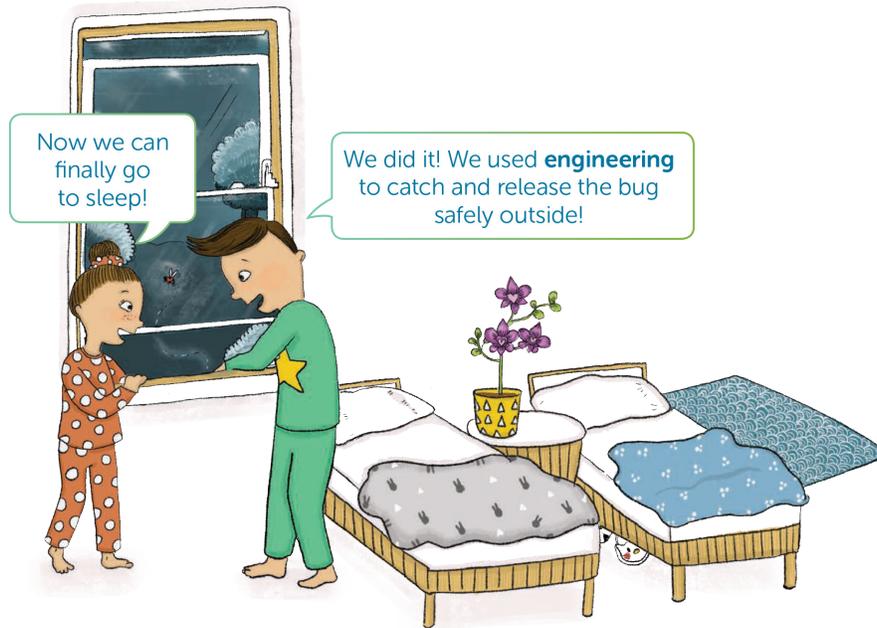


Figure 2.

Families also reported that the activities inspired them to look for more ways to continue learning as a family (Figure 2). This is encouraging because it suggests the EiE Families activities serve as a catalyst, giving families the confidence and interest to seek out additional ways to continue learning together. It's also good news for educators who may see increased STEM interest and engagement from students who choose to do these activities at home with their families.

"These activities gave my kids a lot to think about and helped them start asking questions, being more curious, and wanting to learn more about our human made world." -- Caregiver, Orchard Hills, CA



While the above results are encouraging, it should be noted that these are preliminary findings, and that the non-experimental nature of the evaluation limits our ability to generalize. Still, the response from families suggests the program provides value for caregivers and children looking for fun and educational ways to spend time together. It may also be an effective tool for educators who, now more than ever, are looking for ways to ignite their students' interest and mitigate the learning loss caused by the COVID-19 pandemic.

In early 2023, EiE will be conducting a nationwide experimental trial of the EiE Families program. This Cluster Randomized Trial (CRT) is designed to meet the highest

standards of academic research, Tier 1, as defined by the Every Student Succeeds Act (ESSA). Results are expected in May 2023 and will provide an empirical understanding of the impact of the EiE Families program across a range of topic areas including the effect of family learning on student engagement in the classroom.

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Chris San Antonio-Tunis is Manager, Research & Evaluation, Museum of Science, Boston. He can be reached at csanantonio@mos.org



Christine A. Gentry is an Analyst, Research & Evaluation, Museum of Science, Boston. She can be reached at cgentry@mos.org



Jeremy C. Simon is Senior Data Fellow, Research & Evaluation, Museum of Science, Boston. He can be reached at jsimon@mos.org

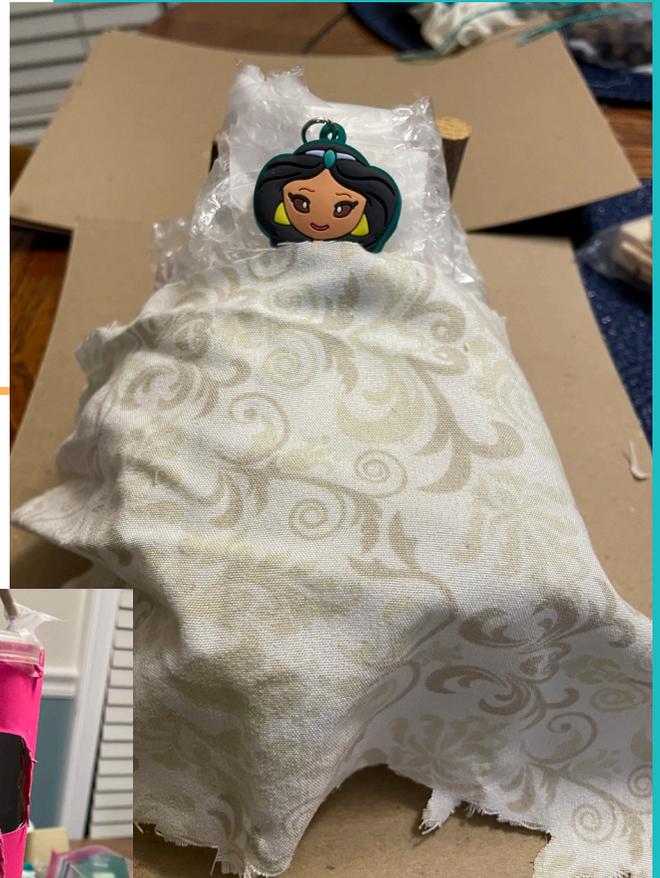
Engineering Our Own Fairytales

By L. Octavia Tripp, Megan Burton, Margaret James Stephens, and Isabelle Scott

Fairytales have been enjoyed for generations by young children around the globe. There are multiple versions of similar stories across cultures such as *Cinderella*, *Yeh-Shen*, *The Rough-Faced Girl*, and *Nyasha*, among others. These stories appeal to all ages by providing exposure to different cultures, aiding in emotional resilience, helping children connect stories to real life, sparking imagination, and offering morals and messages that help students understand decision making. In the past, they have been used in classrooms in the content areas of reading, writing, and the arts. However, classrooms often miss opportunities to connect fairytales to the science, technology, engineering, and mathematics (STEM) that bring the stories to life. Children learn from the mistakes of characters in the stories, which helps them with their critical-thinking skills. Connections can be found in everything we read and communicate. Science and engineering are the impetus stimuli that drive STEM teaching and learning. What better way is there to show how pervasive it is in our world than to integrate cultural artifacts like fairytales to connect reading with STEM. Therefore, one should look at fairytales as opportunities for making connections in cross-cutting designs (NGSS, 2013).



Fairytales are already a part of the elementary school curriculum and can encourage students to problem solve and create design ideas. Most children are already familiar with fairytales so the lessons can focus on utilizing the storylines for their STEM content. In fairytales the ideas for engineering connections are limitless. They can be used



as a springboard for developing engineering lessons. This article describes two examples of engineering design challenges based on fairytales that can be used at the primary and intermediate grades when they are exploring these in their reading classes. Collaboration, critical thinking, problem solving, engineering, creativity, math, technology, and literacy—all of these skills come to life when students participate in activities such as those described below. Building fluency and confidence in these skills can serve students now as well as in their futures (Born, 2021).

Below are two examples of STEM activities that could be integrated into a fairytale unit. *Rapunzel, Rapunzel, Let Down Your Pulley*



is designed for primary grades, but could be adjusted for intermediate grades. *The Princess and the PeaSTEM* is designed for intermediate grades but could be adjusted for primary grades. These lessons are shared to encourage educators to try to design additional STEM challenges that connect to literacy in the classroom. The following Technological and Engineering Literacy Standards and Practices are illustrated through both lessons.

Task Overview for *Rapunzel, Rapunzel, Let Down Your Pulley*

In this lesson, students encounter Rapunzel, who now has short hair and needs to find an alternative way to escape her tower. In the story that students read, Rapunzel had long golden hair and beautiful green eyes. Her parents were unaware that Rapunzel's hair had magical healing powers. To spare Rapunzel from a life as a prisoner forever enslaved, her hair is cut, thereby rendering her magic hair useless. After students hear this story they are asked to brainstorm ways to get Rapunzel out of the tower. In a previous lesson students learned about simple machines. They remembered that a pulley, a simple wooden machine, uses a wheel and rope to lift heavy loads. In the case of "Rapunzel, Rapunzel, Let down your Pulley," students are challenged with creating a pulley that could be used to bring items to and from the tower.

Standards for Technological and Engineering Literacy

STEL-1C - Demonstrate that creating can be done by anyone

STEL-2E - Collaborate effectively as a member of a team

STEL-7B - Demonstrate that designs have requirements.

STEL-7C - Explain that design is a response to wants and needs.

STEL-7D - Discuss that all designs have different characteristics that can be described.

STEL-7G - Apply skills necessary for making in design

Technology and Engineering Practices

TEP-2 Creativity

TEP-3 Making and Doing

TEP-4 Critical Thinking

TEP-6 Collaboration

TEP-7 Communication

Next Generation Science Standards

3-5-ETS-1 Engineering Design: Define a simple design problem reflecting a need or want that includes specific criteria for success and constraints on materials, time, or cost.

Integrated STEM Practices

ISP 1 - use critical and creative thinking to define and solve problems

ISP 2 - collaborate and use appropriate tools to engage in iterative problem-solving

ISP 3 - communicate solutions to problems based on evidence and data

ISP 4 - recognize and use structures in real-world systems

Materials:

- Scraps of building materials such as cardboard pieces, toilet paper rolls
- Sketch paper
- String
- Rope
- Rubber bands
- Tape
- Pencil
- Cylindrical potato chip can
- *Keep it Simple Rapunzel! The Fairytale*

Physics of Simple Machines by Thomas Kingsley Troupe

- Copies of other renditions of the story such as *Really Rapunzel Needed a Haircut!: The Story of Rapunzel as Told by Dame Gothel* by Gunterson, Flaherty, and Alonso or *Rapunzel* by Rachel Isadora.

Lesson Goals:

Students will compare the effects of different pulls on the motion of an object

Students will construct pulleys to make moving an object easier

Students will engage in the practice of design skills and evaluate designs based on criteria, constraints, and standards

Lesson Outline (If implementing with elementary students)

1. Review the story of Rapunzel and introduce *Keep it Simple Rapunzel! The Fairytale Physics of Simple Machines*
2. Introduce simple machines and discuss how a pulley allowed Rapunzel's mother to make it to the top of her tower.
3. Ask what someone might do if they didn't have long hair.
4. Today students will be designing a way for Rapunzel to get a person up the tower, even though she cut her hair.
5. Students then work in teams of 3-4 to design a pulley that could lift a pencil (representing the mother) to the top of a tower made from a potato chip can cylinder. They will begin with a sketch and then design the prototype.
 - i. Constraints
 - a. The design may include no more than 4 types of materials
 - b. The design must be able to lift a pencil without tipping over
 - c. The design must be able to lower a pencil gently so it lands on the ground safely.

6. Students test with one pencil. If they are successful, they are challenged to try the same pulley with three pencils. If they are unsuccessful, they receive feedback and have an opportunity to make revisions.
7. Students then create a story around Rapunzel and what she will bring to her room with the pulley.

***For intermediate grades* expand the lesson to learn about more types of simple machines. Challenge students to include the possibility of designing something to meet the challenge using any of these types of simple machines. Have them use real-world examples and photos of each with labels that are then placed on display: Lever, pulley, inclined plane, screw, wedge, and wheel/axle.

Princess and the PeaSTEM

In this lesson, students explore design and force. They design a bed and mattress that effectively support the princess and the pea while also preventing the princess from feeling the pea when she sleeps. Students will place a marble between their bed frame and mattress. They will test and offer feedback to peers. Once the designs are ready, the beds will be examined using the criteria of sturdiness and comfort. Sturdiness is tested by putting a small figurine doll on the bed and ensuring it can support the marble and the doll. Comfort is actually measured by placing the doll on the bed and then taking the doll off and judging if the marble is still in place and if it creates a visible bump that might be felt if the figurine were a living thing.

Materials:

- Scraps: Cardboard pieces, toilet paper rolls
- Wooden dowels, wooden square and rectangular pieces
- Sponges
- Bubble wrap
- Scraps of cloth

- Markers or crayons
- Marble (representing the pea)
- Cotton balls
- Sketch paper
- Small doll or figurine (if not available one could use a rock, stick, or be created from construction paper by the student)
- *The Princess and the Pea* by Hans Christian Anderson adapted by Janet Stevens (the princess is a tiger)
- Copies of other renditions of the story such as *La Princess and the Pea* by Susan Middleton Elya

Lesson Goals:

- Students will demonstrate an understanding of the balance of forces and weight as they design a mattress and bed that conceal an object even when weight is put upon them.
- Students will engage in the practice of design skills and evaluate designs based on criteria, constraints, and standards.

Lesson Outline (If implementing with elementary students)

1. Read and discuss *The Princess and the Pea*
2. Share that students are to work as partners to design their own bed and mattress for a princess that will be tested by peers, revised, and then presented to the class for a final test. The constraints are:
 - a. Must design both a bed and a mattress that can hold both the marble and your princess.
 - b. The bed may not be longer than 10 inches and may not be wider than 6 inches.
 - c. The marble must be placed between the bed frame and the mattress.
 - d. Be prepared to share why you selected the materials and how they

help either hold up the marble and princess or how they help hide the marble from the princess.

3. Students pre-sketch a design for their bed and mattress, determining materials to use, size, etc.
4. Students will work with partners to design a bed that can hold the marble and princess.
5. Then students will design the mattresses.
6. Trade and test with peers.
7. Discuss tests and make revisions.
8. Apply feedback and concepts of weight and force to adjust the design.
9. After revisions, partners will share their designs and justify the decisions and the information that influenced their choices. The products will be tested and scored by the teacher or a guest judge.

Other engineering ideas for fairytales include designing a bridge for the Billy Goats Gruff to cross, designing a wind-powered carriage for Cinderella, creating a bow and arrow for Robin Hood, building a house for the Three Little Pigs, and creating a boat to help the gingerbread man escape. The ideas are endless and create an engaging way for fairytales to come to life as students engage in problem solving and the engineering design process.

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L. Octavia Tripp, Ph.D. is an Associate Professor of elementary science education at Auburn University. She can be reached at tripplo@auburn.edu



Megan Burton, Ph.D. is an Associate Professor of elementary mathematics education at Auburn University. She can be reached at megan.burton@auburn.edu

Margaret James Stephens and **Isabelle Scott** are undergraduate students in the elementary education program at Auburn University.

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