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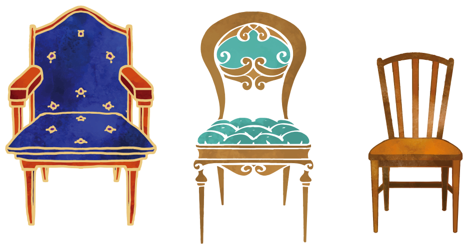
Goldilocks an engineer?



How do you teach engineering to kindergartners? This is a fair question, given the stereotype of STEM workers as lab scientists and number crunchers; however, when approached from a wider perspective, even the youngest of children can be engineers. A framework for K–grade 12 science education defines engineering "in a very broad sense to mean any engagement in a systematic practice of design to achieve solutions to particular human problems" (NRC 2012, pp. 11–12). This aligns closely with the first of the Common Core's Standards for Mathematical Practice (SMP 1): *Make sense of problems and persevere in solving them* (CCSSI 2010, p. 6). Children as young as kindergarten are capable of identifying problems and designing solutions in science and mathematics, and it turns out that many fairy tales provide a rich problem-solution context.

The engineering design challenge described in this article is part of a broader unit of study developed around the story *Goldilocks and the Three Bears* (see **fig. 1**). During the course of four weeks, a kindergarten class examined the story from different perspectives. For example, in one lesson, students considered the attributes of bears and their habitats; in another lesson, they considered the consequences of making safe or unsafe choices. The teacher purposefully "sandwiched" content between the introduction and execution of the design challenge. In this manner, the challenge provided context for understanding mathematics and science content. Use of a familiar story as a basis for identifying and solving a problem increased students' motivation throughout the unit.

Designing a just-right chair

The following is a description of students' experiences in one kindergarten class during

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FIGURE 1

The classic fairy tale *Goldilocks* provided familiar context for kindergartners to understand math and science content as they considered, for example, bears' attributes and habitats and the consequences of making safe or unsafe choices.

The Story of Goldilocks and the Three Bears

Once upon a time, there was little girl named Goldilocks.
She went for a walk in the forest.
Pretty soon, she came upon a house.
She knocked, and when no one answered,
she walked right in.

At the table in the kitchen were three bowls
of porridge. Goldilocks was hungry. She tasted the porridge
from the first bowl."This porridge is too hot!" She exclaimed.
So she tasted the porridge from the second bowl.
"This porridge is too cold," she said.
So she tasted the last bowl of porridge.
"This porridge is just right," she said happily,
and she ate it all up.

After she'd eaten the three bears' breakfasts,
she decided she was feeling a little tired.
So she walked into the living room,
where she saw three chairs.

Goldilocks sat in the first chair to rest her feet.
"This chair is too big!" she exclaimed.
So she sat in the second chair.
"This chair is too big, too!" she whined.
So she tried the last and smallest chair.
"Ahhh, this chair is just right," she sighed.
But just as she settled down into the chair to rest,
it broke into pieces!

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Designing a chair for Goldilocks included testing it using Less Mass Goldilocks and More Mass Goldilocks dolls.

the final two weeks of the Goldilocks unit. We pick up during the introduction to the problem and follow the class as students develop the mathematics skills necessary for success with the challenge.

Before rereading the story to the class, Mrs. Carter announced, "You have heard the story *Goldilocks and the Three Bears* before, but today we are reading it a little differently. Today we are reading like engineers!" After rereading the story, Carter continued, "Goldilocks has a problem, and she needs our help. What is Goldilocks's problem? Talk with your neighbor."

The class decided that one of Goldilocks's problems was that she broke the chair, which led to the design challenge: Design a just-right chair for Goldilocks. The students buzzed with excitement and wanted to know more, so Carter guided them through the design criteria:

- Work in an engineering team to design a chair with a seat, a back, and four legs.
- The chair should balance when different forces are applied.
- Select from a variety of materials (e.g., Legos®, blocks, Lincoln Logs®, Tinker Toys®).
- Plan the design and draw a diagram of the chair before building it.
- Test the chair using the Less Mass and More Mass Goldilocks dolls.
- Revise the design and test again as needed.

Developing content

Carter realized that her students needed to understand some important mathematics and science concepts before approaching the challenge. She introduced the challenge in advance to assist her students with making connections between the content and application. The class began by sorting attribute blocks, and Carter explained that the color, shape, thickness, and size of the blocks are called their *properties* (CCSS.K.MD.B.3). She continued to explain that the properties of a material are what make it more or less useful and that in design, some properties are more important than others. The class discussed the various building blocks available for the chair design and the properties that might be important to consider (e.g., color is a less important property to consider than strength for this challenge).

In a subsequent lesson, the class produced a general definition of *mass*: the amount of stuff (matter) in an object. They "massed" themselves using a large double-beam balance, like those used in doctors' offices. The students used balance scales to compare the mass of various objects and to label them as *less mass* or *more mass* (CCSS.K.MD.A.2). Carter reminded students that they would be testing the strength of their chairs using Less Mass Goldilocks and More Mass Goldilocks. The two dolls are the same size, but by holding them and using balance scales to compare, students could feel and see that one is light and the other, heavy.

Exploring materials for the chair design

Next, Carter read *Homes Everywhere* (Ring 2002) and identified the materials that are used to build homes in the story. Students learned that design choices are often made on the basis of environmental factors: Which materials are readily available? How will weather impact the design? Who will be using the house or chair? Students were tasked with building a model home using some of the materials available in the classroom. While building, they were asked to compare materials and consider the best choices for the chair design. Materials varied in size, shape, color, and ability to fit together. The concept of force was introduced using

Push and Pull (Freeman 1997), and students practiced pushing and pulling on their model homes to observe the effects. The Goldilocks dolls apply a force on the chairs—a chair that withstands the force does not move or fall apart—so students had to carefully consider material choices and design structure.

Planning and designing

After reading *Design It! Build It!* (Ring 2007), Carter addressed the class: "Today we get to work as engineers to solve Goldilocks' problem! We are going to use our engineering design process and all we have learned about forces and materials to create a plan."

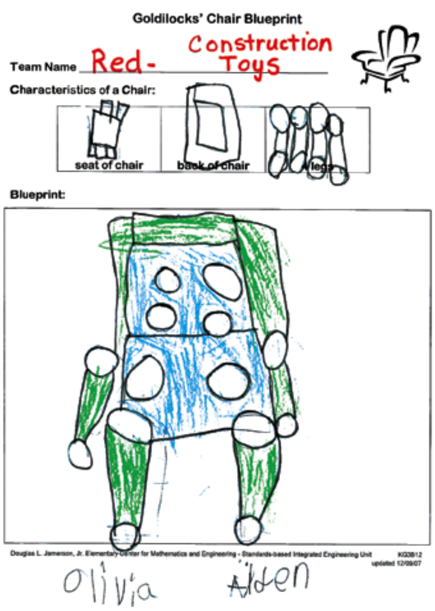
The engineering teams began right away by talking about their ideas for the chair (materials, shape, size, etc.). "I think we should use the big Legos, because they fit together and will be strong," one student suggested.

Another child noted, "We need to make the seat wide enough so Goldilocks doesn't knock it over."

After coming to an agreement, the class drew a blueprint (see **fig. 2**). Once the blueprint received teacher approval, students gathered materials and constructed the chair according to their drawing.

FIGURE 2

Part of the design process included drawing a blueprint of the chair they had engineered before trying to build it.



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When constructing chairs from their plans, students sometimes discovered the chair was not sturdy, so they had to return to the drawing board.

Checking and sharing

Teams used the dolls to check their chairs at multiple times during construction. They used the results of each test to inform their design: Where are the weaknesses? How can we make it stronger? Some teams even decided to abort their plan and start again with a fresh blueprint or different materials. During the design phase, the teacher acted as an observer, allowing students to struggle and persevere through any frustration, while providing just enough scaffolding to keep the teams from breaking down. The final check provided the opportunity for each team to present its chair to the class, discussing materials selection and aspects that made it especially strong or unique. Chair strength was tested against Less Mass Goldilocks, then against More Mass Goldilocks, and the results were recorded on a class chart. The class discussed strengths and weaknesses of each chair, and the teams considered ways to improve their designs.

Considerations

When implementing engineering design tasks with young children for the first time, here are some important aspects to consider:

- Team-oriented tasks and discussions require a good deal of up-front preparation. Children should be guided through multiple experiences in working with teammates, Students were proud to display their chair designs along with their finished products.

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with teachers highlighting the elements of effective teams and the positive examples they observe.

- The engineering design process should be introduced before the design challenge, using minichallenges to guide students through the process. This is particularly important for keeping primary grade students focused and structured.
- The development of related mathematics and science content before the challenge enables all students to engage, not just those with prior knowledge.
- The teacher should be a constant observer, facilitating appropriate discussion and teamwork but allowing enough space for children to resolve conflicts independently.

The benefits of the activity were well worth the preparation time. Carter noted a significant increase in student motivation not only during the design challenge but also throughout the unit. In addition to developing a beginning understanding of the relationship between science and mathematics, students developed collaboration and problem-solving skills that persisted throughout the school year.

Integrating simple design tasks

STEM education should be accessible for everyone, regardless of gender, ethnicity, ability, or age. One way this can happen is through the integration of simple design tasks into broader units of study. The Goldilocks example described above, like many fairy tales, provides a motivating problem-solution context accessible to kindergartners. Young children have a natural ability to solve problems that—when harnessed—will help them—

- see the connectedness among mathematics, science, literature, and the real world;
- communicate as part of an effective team; and
- over time, develop into the creative problem solvers that our society needs.

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