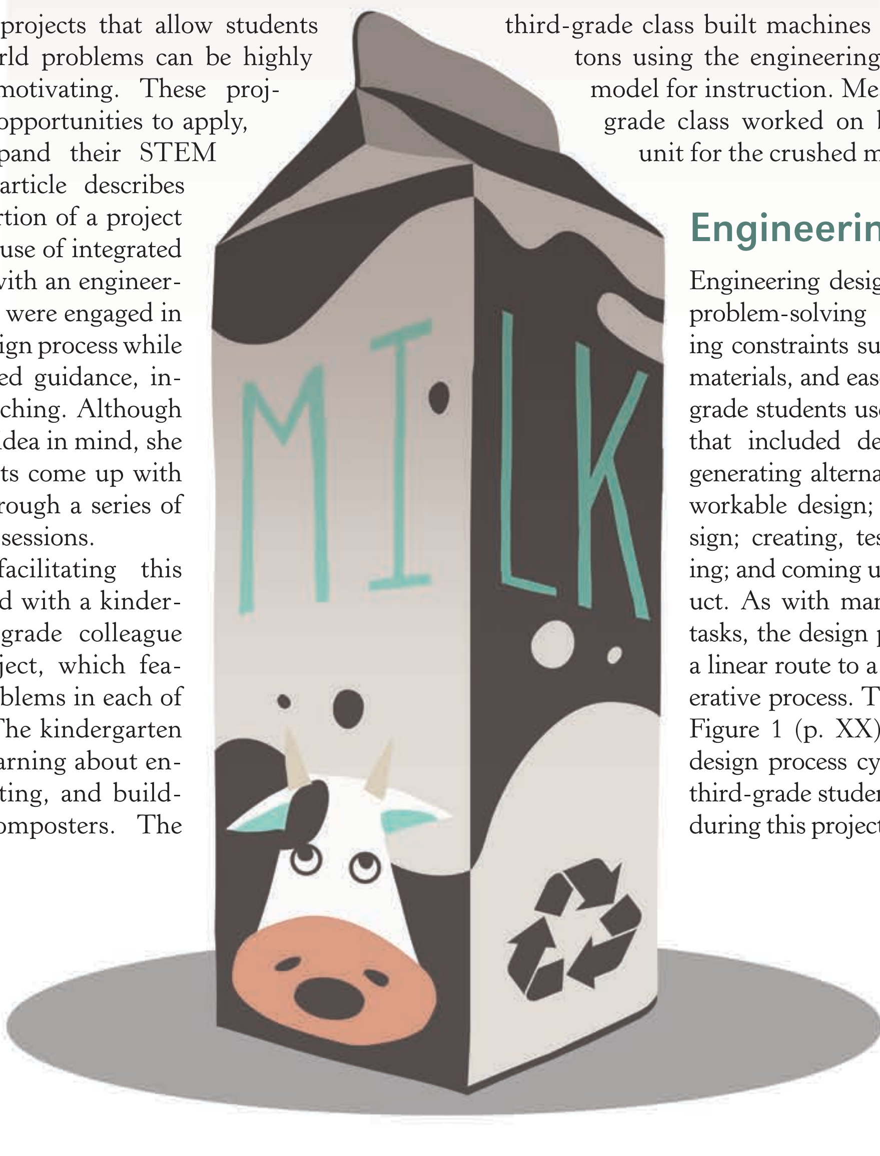
Smashing Milk Cartons

Third-grade students solve a real-world problem using the engineering design process, collaborative group work, and integrated STEM education.

By Debra Monson and Deborah Besser

Interdisciplinary projects that allow students to solve real-world problems can be highly engaging and motivating. These projects give students opportunities to apply, integrate, and expand their STEM knowledge. This article describes the third-grade portion of a project that highlights the use of integrated STEM education with an engineering focus. Students were engaged in the engineering design process while the teacher provided guidance, information, and coaching. Although the teacher had an idea in mind, she chose to let students come up with the project idea through a series of informational class sessions.

The teacher facilitating this project collaborated with a kindergarten and sixth-grade colleague to create this project, which featured different problems in each of the three grades. The kindergarten class spent time learning about engineering, composting, and building individual composters. The third-grade class built machines to crush milk cartons using the engineering design cycle as a model for instruction. Meanwhile, the sixth-grade class worked on building a storage unit for the crushed milk cartons.



Engineering Design

Engineering design requires creative problem-solving while considering constraints such as time, money, materials, and ease of use. The third-grade students used a design process that included defining a problem; generating alternatives; developing a workable design; analyzing that design; creating, testing, and improving; and coming up with a final product. As with many real engineering tasks, the design process often is not a linear route to a solution, but an iterative process. The model shown in Figure 1 (p. XX) of an engineering design process cycle illustrates what third-grade students were engaged in during this project.

FIGURE 1.

Engineering design process.

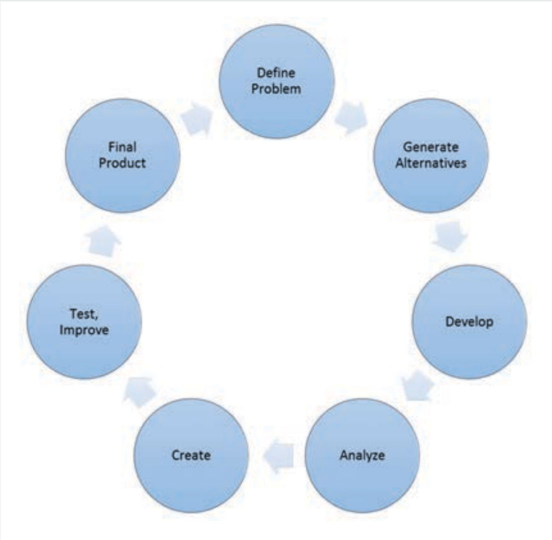
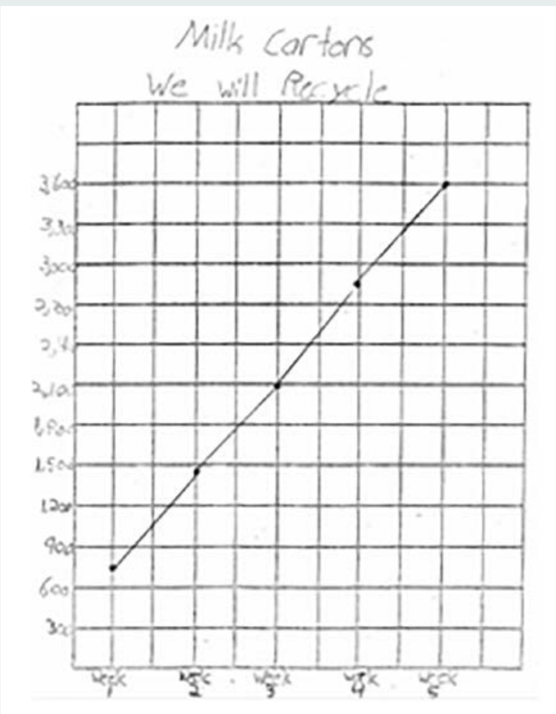


FIGURE 2.

Milk cartons used over time.



Define the Problem

The third-grade teacher began the unit by helping her students gather information to fully define a problem and understand the constraints. Students were shown videos about composting and the use of landfills as a way to open discussion on a problem they may be able to solve (see Resources). The teacher explained that they would be studying recycling and what garbage can do to the environment. She told students they would be watching videos to help them understand the effect that humans have on the environment.

After watching the videos about the composting and landfills, students brainstormed ways they could reduce the impact of the garbage they produce at home or school. The teacher was thrilled that a student suggested exploring ways to recycle or compost the milk cartons they use at lunch, as that was the problem she intended to have them solve.

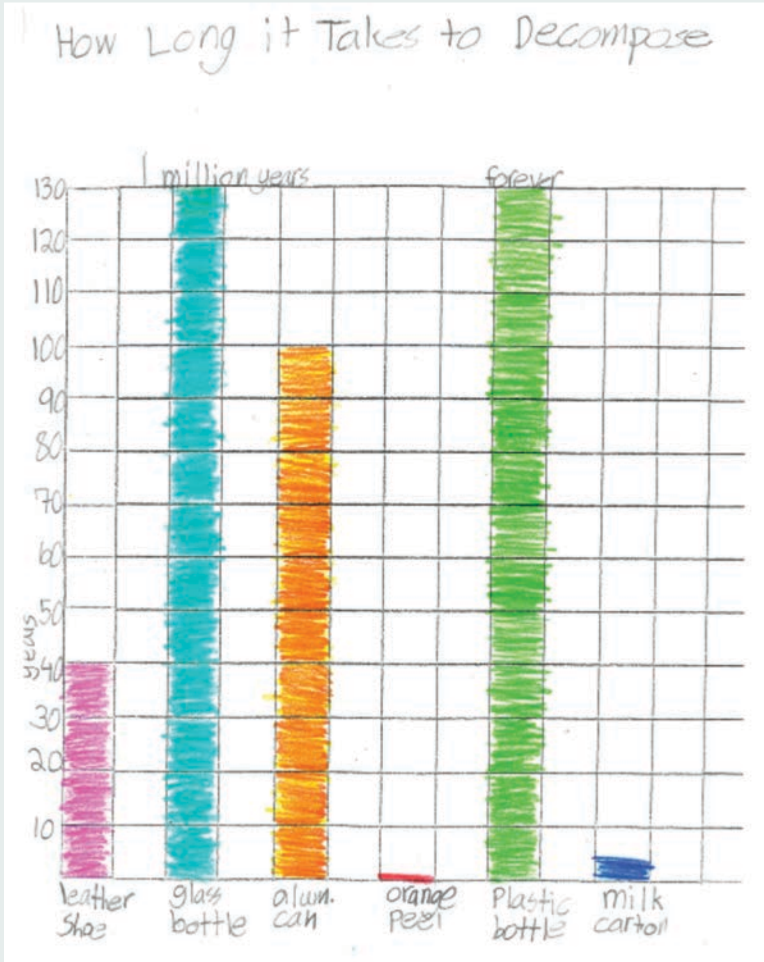
In a summer course focused on engineering education, the kindergarten, third-, and sixth-grade teachers at this school created a unit plan that they thought could be implemented the following year, based on the engineering design process. The summer course instructors encouraged the participants to begin with a real-world problem. This milk carton problem was the real-world problem these teachers thought the students would embrace. They chose it with the hope that all three grades would be able to learn part or all of the engineering design cycle through the exploration of a solution. By introducing students to the ideas of recycling, composting, and the excess garbage produced by the milk cartons, the third-grade teacher was hopeful that the students would realize this was a problem they could solve. Alternately, she could have introduced the problem and done essentially the same activity through a more direct approach but her goal was for the problem to come from the students and she therefore took the chance that the students would come to same conclusion as she had.

The teacher brought the students to the cafeteria to see all the garbage generated from lunch. She invited Bob, the custodian, into the classroom to share how the milk cartons, especially those with milk still in them, added to his workload. Students in third grade initially defined the problem as reducing the amount of garbage that Bob had to haul but, along with that solution, students realized they could compost or recycle the milk cartons. In order to solve this problem, students needed to find a way to empty and store the milk cartons for recycling or composting. This introduced a new problem because the space necessary to store the milk cartons would be great. Students then defined the real problem as developing a way to crush the milk cartons to reduce space until they could be composted or recycled. The third graders focused on emptying and crushing the milk cartons, while the sixth-grade class worked on creating a storage container. The kindergarteners focused on the impact of composting.

Students collected data on the number of milk cartons used per day during both snack and lunch time and graphed this data over time (see Figure 2). They researched how long it takes various lunch items to decompose and graphed this data (see Figure 3). This information was added to the personal story of the custodian to help the students clearly define the problem and begin to create a solution.

FIGURE 3.

Amount of time it takes various lunch items to decompose.



Generate Alternatives, Develop and Analyze Solutions

In keeping with the engineering design process, prior to any building, students individually brainstormed solutions and used graph paper to draw potential solutions and generate alternatives. Students were provided some materials to think about as they began developing their solutions: soup cans, a potato masher, 6 in. × 3 in. wooden blocks, PVC valves, other cylindrical shapes, and rectangular prisms. Students brought in a bucket and some string to add to the materials available. Materials that were brought in needed to be student-friendly and have a very low (or no) risk of injury to the students. Beyond material constraints, it was identified that ALL students, from kindergarten to eighth grade, needed to be able to safely use the machine to crush their milk cartons. No models were created at this point; this was just a brainstorming phase to generate alternatives and develop solutions.

Students were then placed into heterogeneous groups of three or four, with both boys and girls in each group, where they shared individual solutions, brainstormed beyond those solutions, and synthesized an optimal solution. The teacher remained a facilitator and let the students decide which solutions were reasonable without trying to lead them down a set path. They analyzed their own solution, as a group, in order to choose one to create.

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FIGURE 4.

The winning design.

Create, Test, and Improve

Students moved into the final prototyping phase in their small groups. Prototypes were created and then tested—first by third graders and then by kindergarteners—with the requirements that the machine could easily crush the milk carton and kindergarteners were able to use the machine. The teacher was careful to monitor the use of the prototypes during creation and testing to eliminate any safety concerns. Goggles were worn to avoid injury. Critical to the learning process was the teacher-facilitated discussion on possible improvements and steps needed for redesign. Questions students were asked included: How easy is it to use? How effective is it? How quick is it? Are there improvements that can be made? Students then made improvements and prepared to present to the class.

Final Product

The final product of each group was then presented to the class and put up for a vote on the best choice to fit the needs of the problem. To be the most successful project, the carton crusher needed to be effective, safe, quick, and inexpensive. The winning design (by class vote) ended up being the simplest: a pail to pour milk in followed by a block of wood to crush the milk carton in a pan to prevent splashing (see Figure 4).

This solution, however, created a new problem, as so often happens in the real world. The kindergarten class was unable to crush their own cartons with the machine. So, how did the students solve this new problem? They agreed that the older students would simply help them crush their cartons while the classroom teachers supervised the crushing. This "non-engineering" solution served as an important lesson in the need for the "4Cs": communication, collaboration, critical thinking, and creativity.

Connections

The teacher in this classroom led a student-driven engineering design challenge that integrated science, engineering, and mathematics as well as other content areas and skills. Students were actively engaged in groups, sketched possible problem solutions, voted on designs, and wrote reflections on the process. Students were interviewed after the final product had been chosen and asked, "Will you please tell me about your engineering project?" Students were articulate when describing the process they went

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through and clearly stated environmental and practical reasons for doing this project.

An unexpected element that surfaced during the interviews was the students' compassion for the custodian and the awareness of the amount of garbage they were generating from the milk cartons. A student explained:

"We tested how much garbage we throw away a day and we got somewhere around two hundred pounds I think. And Bob says it's really heavy. Each day we recycle milk cartons, we'll reduce about 15 pounds on each bag, so it'll be lighter for Bob."

Implementing Your Own Challenge

This was the students' first introduction to engineering and integrated STEM. Every student interviewed (about half the class) responded positively to the challenge, stated they would like to do another challenge, explained how actively engaged they were, and agreed that having failures was perfectly acceptable. This project helped further these students' understanding of an engineering design cycle, created opportunities for collaboration, and encouraged them to solve a problem they felt was important.

As teachers plan for their own real-world engineering challenge, there are some important things to consider. First, can students help define the problem? If they can, what information do they need to be able to do so? Next, what are the constraints? Will you allow them to use unlimited materials, choose what they use, or attach a cost to each material used? How can you highlight engineering design throughout the challenge? For this challenge, success was measured through the completion of a solution, but teachers can consider other formative assessments along the way to ensure active student engagement throughout the project. It is important to include check-in points throughout the activity to monitor progress of the individuals as well as the groups. The instructor assessed students' participation in activities through informal observation based on participation, used a KWL chart (Ogle 1986) to assess student understanding at various points in the process (what do you Know, what do you Want to know, and what did you Learn?), and used classroom discussion, including student answers to verbal questions, as a way to check progress and understanding. The teacher collected their graphs, observed group discussion, and carefully monitored student engagement. In addition to informal assessments, a more formal rubric could be used to give students feedback based on the engineering design process used (see NSTA Connection).

One piece of this integrated work that could be improved was taking time to explicitly point out the connections between different content areas. When students in the interviews were asked if they did mathematics, most responded that they did not, even though they mentioned the graphing and calculations they had to do. The teacher agreed that next time she would like to spend time discussing the different content necessary to complete a problem like this. Making connections is a key component as we look to encourage all students to learn STEM concepts in the classroom. ■

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NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press. *www.nextgenscience.org/next-generation-science-standards.*

Ogle, D.M. 1986. KWL: A teaching model that develops active reading of expository text. *The reading teacher* 39 (6): 564–570.

Resources

Gibbon, G. 1996. *Recycle! A handbook for kids.* Little Brown Books for Young Readers.

Stover, J. 1989. *If everybody did.* Greenville, SC: JourneyForth.

Woolhouse, C. The Three Rs Reduce Reuse Recycle. *www.youtube.com/watch?v=wtoeZ9Nkeqk.*

NSTA Connection

Visit *www.nsta.org/sc1507* for the rubric.

Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013)

2-PS1 Matter and Its Interactions

www.nextgenscience.org/2ps1-matter-interactions

Performance Expectation *The materials/lessons/activities outlined in this article are just one step toward reaching the Performance Expectations listed below. Additional supporting materials/lessons/activities will be required.*	**Connections to Classroom Activity**
2-PS1-2 Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.	Students build models to observe and test the ability of the mechanism and materials to provide the crushing solution.
Science and Engineering Practices	
Planning and Carrying Out Investigations Analyzing and Interpreting Data Constructing Explanations and Designing Solutions Engaging in Argument From Evidence	Students • plan simple investigations of materials and mechanisms available to solve the problem. • construct models of solutions. • collaboratively plan and conduct and investigate possible solutions and collect data. • analyze data collected from testing to determine if the materials and mechanism solve the crushing problem. • construct explanations of which materials and mechanisms best solve the problem. • engage in argument from evidence.
Disciplinary Core Idea	
PS1.A: Structure and Properties of Matter • Different properties are suited to different purposes. • A great variety of objects can be built up from a small set of pieces.	Students evaluate the materials and mechanisms available to solve the problem.
Crosscutting Concepts	
Cause and Effect Energy and Matter	Students use models to test crushing performance of the models and in turn gather evidence to support or refute claims. Students break milk cartons into smaller pieces to change the volume and surface area of the carton.

Connecting to the *Common Core State Standards* ((NGAC and CCSSO 2010)

CCSS.Math.Content.3.MD.B.3

Draw a scaled picture graph and a scaled bar graph to represent a data set with several categories. Solve one- and two-step “how many more” and “how many less” problems using information presented in scaled bar graphs.

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.