In the simplest of terms, a makerspace is “a place where young people have an opportunity to explore their own interests; learn to use tools and materials, both physical and virtual; and develop creative projects” (Fleming 2015, p. 5). In reality, they are so much more than that! Makerspaces have become very popular in education because they “provide hands-on, creative ways to encourage students to design, experiment, build, and invent as they deeply engage in science, engineering, and tinkering” (Cooper 2013). Not only do makerspaces provide a safe learning environment for students to develop their 21st century skills of critical thinking, creativity, communication, and collaboration, they also promote the idea of “moving from consumption to creation and turning knowledge into action” (Fleming 2015, p. 7).

Second graders turn knowledge into action as they engineer solutions for a real-world problem in a school makerspace.

By Laura Kitagawa, Elizabeth Pombo, and Tina Davis
In 2016, our private preK–8 school in Silicon Valley opened its first official makerspace, the Imaginarium. The second-grade homeroom teachers and I, the K–2 science enrichment teacher, were inspired to create a cross-curricular Project Based Learning (PBL) unit that would utilize our new innovative makerspace and encourage our students to apply their STEM skills to become responsible, productive citizens. This eco-friendly unit about ocean plastic pollution targets the K-2-ETS1 Engineering Design Standards (NGSS Lead States 2013, p. 21); follows the 5E instructional model (Bybee 2009); and contains the Essential Project Design Elements of the Buck Institute for Education (BIE) Gold Standard PBL (see Table 1).

### Engage

We began this 6–8 week unit with a thought-provoking gallery walk. In preparation for this entry event, I printed out color photos of ocean plastic pollution and items made from recycled plastic. I placed these photos back to back inside sheet protectors and taped them onto the desks with the pollution photos facing up. When the students entered the classroom, they were given instructions to analyze each photo and discuss their observations with their peers. As they walked around the room, many students shared their prior knowledge and past experiences regarding ocean plastic pollution. Overall, students were shocked by the extent of plastic pollution and saddened by its harmful effects on marine life. Next, students were instructed to flip over the photos and go on another gallery walk. Students initially questioned how these photos related to each other and to ocean plastic pollution. But eventually, they realized that all of these items were made from recycled plastic. Students were surprised by the diversity of items including clothing, shoes, toys,

<table>
<thead>
<tr>
<th>Table 1. Essential Project Design Elements of a BIE Gold Standard PBL.</th>
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<tr>
<td><strong>Project Design Elements</strong></td>
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<tr>
<td>Key Knowledge, Understanding, and Success Skills</td>
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<tr>
<td>Challenging Problem or Question</td>
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<tr>
<td>Sustained Inquiry</td>
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<td>Authenticity</td>
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<td>Student Voice and Choice</td>
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<td>Reflection</td>
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<td>Critique and Revision</td>
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<td>Public Product</td>
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furniture, and even cell phone cases. As a preassessment, students recorded their initial thoughts and observations on a *Plastic Pollution in the Ocean* response sheet (see NSTA Connection). Our students were now full of questions and curiosity!

**Explore**

To investigate plastic pollution on a more personal level, we went on a field trip to a local recycling center. There, students observed the magnitude of the problem firsthand and learned from recycling experts how discarded items are sorted for recycling, compost, or trash. Additionally, the homeroom teachers invited our custodian to come into the classroom and share his concerns about the increasing amount of trash at our school. Coincidentally, we had just started a new lunch program that used additional food packaging, which was overflowing our garbage bins (PBL Authenticity).

**Explain**

Over the next few science classes, students learned about ocean plastic pollution and its harmful effects on marine life (PBL Key Knowledge, Understanding, and Success Skills). I used a variety of resources, including picture books, online websites, and short videos (see Resources). I like to read picture books because they help students make important personal connections, and they are “powerful instructional tools for meeting the needs of a variety of students with diverse learning styles” (Flippo 1999). There are also many effective, hands-on activities to help students visualize ocean plastic pollution and gain a deeper understanding of its long-term, negative effects. The Monterey Bay Aquarium provides some great ones, like *Gyre in a Bottle* and *Shower Curtain Watershed*, which can be easily modified for younger children (see Internet Resources). After a whole-class discussion about the 3Rs (Reduce, Reuse, and Recycle), students brainstormed different ways to reduce plastic pollution at our school and decided to start a yearlong, plastic bottle-recycling program.
Elaborate: Engineering Solutions in a Makerspace

Time to turn knowledge into action! For this project, the second graders worked in the Imaginarium and followed the steps of the Engineering Design Process (Ask, Imagine, Plan, Create, Improve) as described by Engineering is Elementary (see Internet Resources). EiE is a hands-on, inquiry-based, engineering curriculum for grades 1–5 that promotes problem solving, teamwork, communication, and collaboration.

Step 1: Ask

We began with the driving question: How can we make recycling plastic bottles fun and sustainable at our school? (PBL Challenging Problem or Question). To get the students’ creative juices flowing, I showed two Fun Theory videos, Piano Staircase and The World’s Deepest Bin, which demonstrate that “fun is the easiest way to change people’s behavior for the better” (see Internet Resources). With that in mind, I presented the engineering design challenge: create a fun collection container that makes people want to recycle plastic bottles. I explained the criteria (the container must fit over a 14-gallon bin and have at least one opening for bottles) and the constraints (it must be built using only the provided materials and its dimensions cannot exceed 3 to 4 feet).

Step 2: Imagine

Confined only by the walls of our makerspace, the second graders let their imaginations run wild. Using whiteboards and dry-erase markers, students enthusiastically brainstormed and sketched their designs. “The most important quality of a makerspace is that it encourages creativity. … The culture in a space should support the idea that anything is possible” (Thomas 2013). However, some of the students’ designs were a little too ambitious, like a large conveyor belt that transported bottles directly from our school to the recycling center, or a vending machine-like container that gives you money or candy in exchange for plastic bottles. Although we appreciated their “out of the box” thinking, literally, we had to remind these students of the original project constraints before moving on.

Step 3: Plan

We divided the students into cooperative groups of three or four based on a variety of factors, including student choice, social dynamics, and compatibility. Each team discussed the desired look, theme, and features of their new recycling container and, after some collaboration, decided on a final group design that incorporated everyone’s ideas (PBL Student Voice and Choice). Team designs included a variety of carnival-like games, human faces, and even a hungry cat. Using their Engineering Design Notebooks (see NSTA Connection), students sketched a detailed plan of their group’s design and created a list of required materials like wood, screws, paint, duct tape, and even LED lights and pre-recorded sounds (PBL Reflection). At this point, we weren’t sure if lights and sounds would be feasible, but we were hopeful that we could find someone with the expertise to help us.

Step 4: Create

Using their design plans as a reference, teams worked together to build full-scale prototypes of their containers with large cardboard boxes, safety cutters, and lots of duct tape. Safety cutters with dual recessed blades are recommended to allow students to work autonomously and prevent injuries. While some teams were able to build prototypes that accurately resembled their plans, others realized that they needed to switch to easier-to-build designs. Throughout this iteration process, students continually tested their prototypes and
made adjustments accordingly until they achieved a final working model. For example, one team discovered that their bottle openings were too small, so they had to make the holes larger. Another team discovered that their prototype kept falling over, so they had to redistribute the weight of the pieces to make it more balanced (PBL Critique and Revision). In science, I like to tell my students that the acronym FAIL stands for the First Attempt In Learning. … The earlier we fail, the quicker we will succeed. Fortunately, a makerspace “encourages a growth mindset, which tolerates risk and failure and maybe even encourages it … a necessary step on the road to success and innovation” (Fleming 2015, p. 9).

**Step 5: Improve**

Our second graders were now ready to create sturdier models of their cardboard prototypes. In preparation, we purchased the necessary building supplies for under $150 (see NSTA Connection for a supply list) and pre-cut the tempered hardboard into the exact dimensions of each group’s prototype. With the help of parent volunteers, teams worked together to assemble the pieces of their containers using duct tape, hot glue guns, drills, hammers, and screwdrivers. We found that pre-drilling small holes into the tempered hardboard before fastening with screws worked the best. Once the containers were built, students decorated them with acrylic paint and letter stencils. We also sprayed them with a waterproof, clear coating and placed them onto wheeled carts for easy mobility. Always provide adult supervision and guidance when using tools with children. Safety glasses are required for eye protection. Follow guidelines for working with paints, such as proper ventilation.

We were very lucky to have many parent volunteers, especially two dedicated fathers who reinforced the recycling containers and added LED lights and pre-recorded sounds based on each group’s specifications. Unfortunately, we later had to remove the electronic components because of too many curious little hands. Although the construction of these containers required adult assistance, we treasured the community involvement and understood that “the collaborative environment of a makerspace allows an individual to embrace and even seek out challenges beyond his or her comfort zone” (Fleming 2015, p. 10). Makerspaces are especially beneficial for students with learning differences or spe-
cial needs because they provide the encouragement and support necessary for all students to shine and succeed. Through open-ended explorations and hands-on projects, students of all ability levels are motivated and empowered to learn STEM concepts in a safe and engaging way.

The Big Reveal

At last, the innovations were ready to be shared with the world! First, the second graders created an introductory video for the other classrooms that described ocean plastic pollution and encouraged students to use their recycling containers to reduce plastic pollution at our school. Then, at our annual Thanksgiving Feast, students presented their final masterpieces to the school community (PBL Public Product). The whole campus buzzed with excitement and curiosity. Students from preschool through eighth grade, even teachers and parents, eagerly tested out the containers, one after another, while the second graders proudly stood nearby sharing the details of their creations.

Further Extensions

After the big reveal, students wrote persuasive letters (PBL Public Product) to local community officials of their choice (PBL Student Voice and Choice). Throughout the school year, students worked in collaborative committees (maintenance, advertising, collection, sorting, recycling, and treasury) to maintain a schoolwide recycling program (PBL Sustained Inquiry). Every Friday afternoon, each committee went through a checklist of action items (see NSTA Connection). For example, the maintenance committee repaired any broken containers, while the treasury committee kept a log of the profits earned after the homeroom teachers exchanged the bottles for money each weekend. In addition to recycling, the second graders also reused many plastic bottles to create fish art projects and plant terrariums. To wrap up our unit, we went on a field trip to Natural Bridges State Beach to pick up trash along the shore and observe marine life in the tide pools. We also visited the Seymour Marine Discovery Center, where students donated the profits from the recycled bottles to support future marine education and research (PBL Authenticity).

Evaluate

In order to evaluate our students’ learning, we used a variety of formative and summative assessments. Throughout the unit, we observed and recorded the students’ interactions and conversations with peers and experts. We evaluated the students’ engineering skills as they were brainstorming, building, testing, and reiterating in the makerspace. We conducted student interviews regularly to gain insight into their thought processes and understandings. We used engineering design notebooks, committee checklists, and weekly recycling logs to assess students’ design plans, explanations, calculations, and reflections. Last, we evaluated each team’s final container, presentation, and persuasive letters to local community officials. The BIE provides many helpful rubrics for creativity, innovation, and presentations (see Internet Resources).
Conclusion

The makerspace provided our students with the tools to turn STEM knowledge into action, plastic pollution into a solution, and negative human impact into a positive one. Many students were inspired to start recycling at home, clean up local parks on the weekends, and one student even asked to pick up trash on the beach for his birthday! At the 2014 White House Maker Faire, President Obama stated, “you never know where this kind of enthusiasm and creativity and innovation could lead.” Who knows? Maybe in the future, one of our second graders will invent an eco-friendly alternative to plastic! All thanks to a little makerspace and a whole lot of imagination!

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References


Resources


Internet Resources

Buck Institute for Education: Gold Standard PBL Essential Project Design Elements
www.bie.org/object/document/gold_standard_pbl_essential_project_design_elements

Buck Institute for Education: Essential Project Design Elements Checklist

Buck Institute for Education: PBL Rubrics
www.bie.org/objects/cat/rubrics

Documentary Trailer for A Plastic Ocean
www.plasticoceans.org/film

Engineering is Elementary: Engineering Design Process
www.eie.org/overview/engineering-design-process

Fun Theory videos: Piano Staircase and The World’s Deepest Bin
www.thefuntheory.com

Monterey Bay Aquarium: Ocean Plastic Pollution Education
www.montereybayaquarium.org/conservation-and-science/our-priorities/ocean-plastic-pollution

Monterey Bay Aquarium: Ocean Plastic Pollution Summit Hands-on Activities
www.montereybayaquarium.org/conservation-and-science/our-priorities/ocean-plastic-pollution

National Geographic Video: Kids Take Action Against Ocean Plastic

National Geographic Video: How Can We Keep Plastics Out of Our Oceans
www.youtube.com/watch?v=HQTUWK7CM-Y

Plastic Pollution websites with data and resources
www.plasticoceans.org
www.theplasticpickup.org
http://plastic-pollution.org

NSTA Connection

Download the response sheets, engineering design notebook template, a list of makerspace supplies, plus checklists and recycling log, at www.nsta.org/SC1803.
Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013):

<table>
<thead>
<tr>
<th>Performance Expectations</th>
<th>Connections to Classroom Activity</th>
</tr>
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<tbody>
<tr>
<td><strong>K-2-ETS1-1.</strong> 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.</td>
<td>• conduct research about plastic pollution by visiting a local recycling center, interviewing our school custodian, reading informational texts, watching videos, and analyzing online data and photos.</td>
</tr>
<tr>
<td><strong>K-2-ETS1-2.</strong> 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.</td>
<td>• sketch and label designs of recycling containers, work in a makerspace to build and test cardboard prototypes, and modify structures to improve functionality and performance to solve a problem.</td>
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**Science and Engineering Practices**

- Developing and Using Models
  - design, build, and test cardboard prototypes in a makerspace.
  - build sturdy recycling containers to collect plastic all year long for a schoolwide recycling program.
  - communicate and collaborate with teammates, present final containers to the school community, and write persuasive letters to community officials.

- Constructing Explanations and Designing Solutions
- Obtaining, Evaluating, and Communicating Information

**Disciplinary Core Ideas**

- **ETS1.B: Developing Possible Solutions**
  - Sketches and models are helpful to represent possible solutions.
  - **ESS3.C: Human Impacts on Earth Systems**
    - Human activities have both positive and negative impacts.
    - **Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth’s resources and environments.**
  - Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth’s resources and environments.
    - **investigate plastic pollution to discover the magnitude of the problem and how to remediate the issue.**

**Crosscutting Concepts**

- **Structure and Function**
- **Cause and Effect**
  - • improve the structure of their recycling containers to optimize their function.
  - • observe the negative effects of ocean plastic pollution and learn to make better choices that positively impact the Earth.