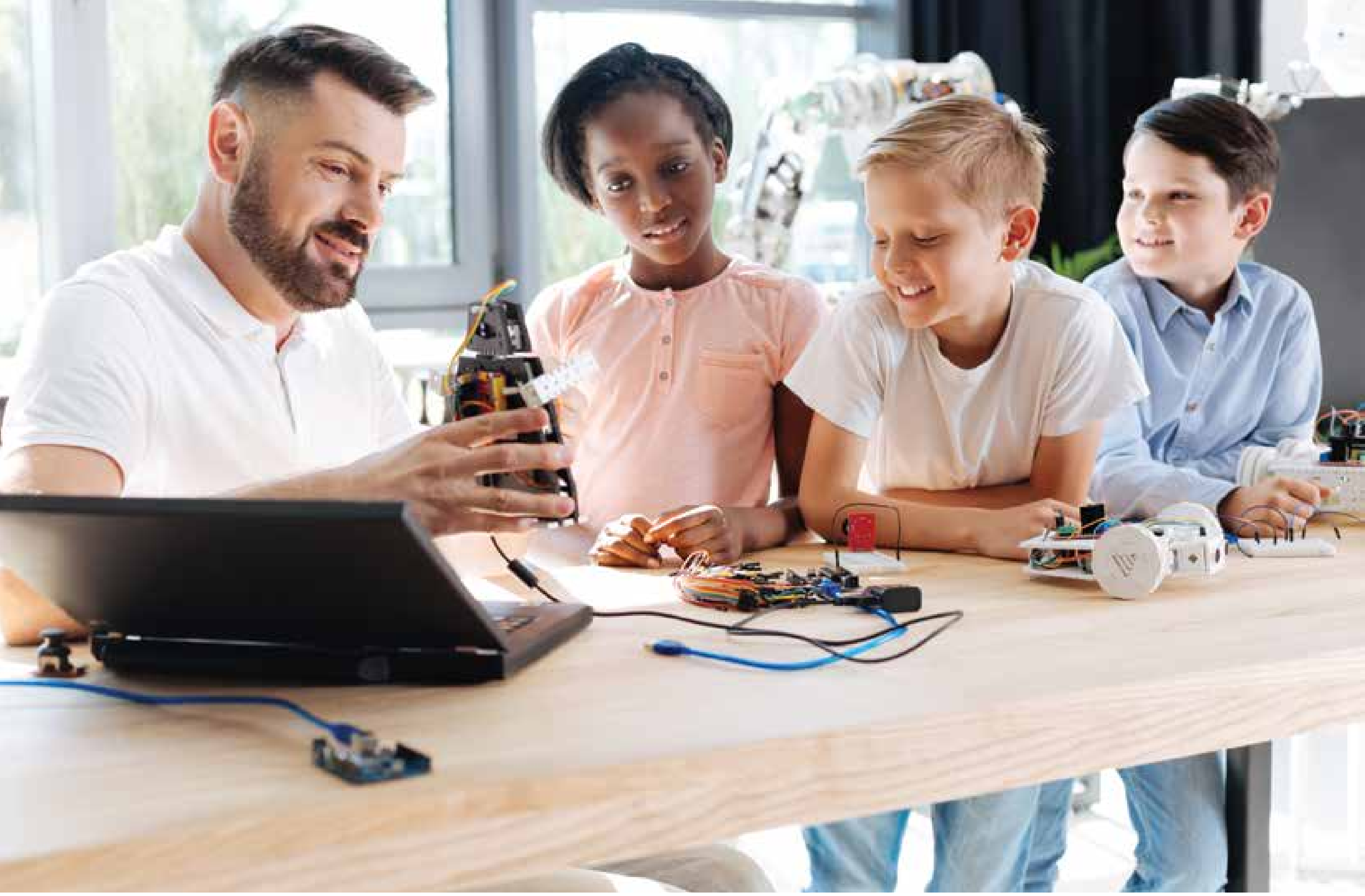


School Maker Faires

This event blends *Next Generation Science Standards* goals with the concepts of the Maker Movement.

By Danielle Harlow and Alexandria Hansen

The Maker Movement (Dougherty 2012) highlights innovation and creativity through "activities focused on designing, building, modifying, and/or repurposing material objects, for playful or useful ends, oriented toward making a 'product' of some sort that can be used, interacted with, or demonstrated" (Martin 2015, p. 31). When engaged in these types of activities, children explore materials, learn and try out new skills, and fiddle with technology.

We believe this is a powerful way to learn. Even the White House has endorsed making as a productive way to stimulate STEM interest and learning and established both the annual National Maker Faire at the White House (Kalil and Miller 2014) and the Nation of Makers initiative. While making is not discipline-specific, it is particularly well suited to addressing the engineering standards and practices included in the *Next Generation Science Standards* (NGSS Lead States 2013).

Maker Faires, communitywide celebrations of making, have been hosted across the world, with the largest of these attracting 100,000 visitors annually. At these events, people of all ages and of various careers and hobbies gather to showcase work and learn from one another. Some exhibitors set up booths displaying things they have built (or are still working on); others host hands-on workshops to teach skills such as soldering. Visitors wander the grounds, following their inspiration and curiosity, and leave with new ideas and plans. Elementary schools have begun hosting smaller events modeled after maker faires. Here, we call these events School Maker Faires, the name given to school-based maker faires that are licensed under Maker Media. While any school can host a Maker event, registering the event (for free) with Maker Media (*makerfaire.com/global/school*) provides permission to use the School Maker Faire logo and to access a community of teachers and administrators organizing other School Maker Faires and resources for planning and hosting a School Maker Faire. These events typically showcase student work and work-in-progress to families and the community while also providing opportunities for attendees to make alongside students and teachers. During the 2015–2016 year, we emphasized maker education in a science methods course for preservice elementary school teachers. The culminating activity was that the teacher candidates facilitated a School Maker Faire for local elementary school students. Below we discuss the course that supported their design and assessment of a maker education activity and the culminating event.

TABLE 1.

School Maker Faire activities.

Preservice Teacher Stations	Description	*NGSS* Alignment
Bird feeders	Students will be offered a variety of recyclable materials and use them to craft/build bird feeders. The bird feeder's purpose is to provide birds with easy access to seed or water.	K-ESS3-3; K-ETS1-2; 3-LS4-4
Play-Doh	We will be providing ingredients that the students will use in an exploratory setting to make modeling clay. The students will be expected to measure out ingredients to use mathematical and computational thinking.	5-PS1-4
Lunar lander	Design and build a vehicle that will land on the Moon and protect the astronauts inside.	K-ETS1-2
Magnetic painting	Objects in contact exert forces on each other (friction, elastic pushes and pulls). Electric, magnetic, and gravitational forces between a pair of objects do not require that the objects be in contact—for example, magnets push or pull at a distance. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. At this station, students will use magnets to paint.	3-PS2-3
Magazine art	The process of recycling paper goods takes time and energy and produces carbon emissions. Finding a way to reuse paper goods ourselves reduces energy use in recycling. We chose to have three stations related to reusing old magazines. At this station, you will make recycled magazine bracelets.	4-PS3-2; K-ESS3-3
Make a game controller	Students will be exploring with programming and circuits to gain an understanding of how circuits work. They will be using fruits such as oranges and bananas to play games and do activities on the computer, rather than using the keyboard.	1-PS4-4; 4-PS3-2; 4-PS3-4

Course Design

The preservice elementary school teachers in our program were enrolled in a 13-month masters and teacher credential program. All had completed an undergraduate degree prior to entering the program. Elementary science methods was held during the second half of the program. While the course addressed many issues related to science learning, here we discuss only those activities and considerations that relate to maker education.

On the first day of class, students were introduced to the *NGSS* and to Maker Education through a shadow puppet activity. The preservice teachers created shadow puppets and a short video that used the shadow puppets to demonstrate something about one of the disciplinary core ideas. The preservice teachers designed storyboards, created shadow puppets, and explored light and shadow. While the preservice teachers were free to choose any area of science to create their video about, the reflection following this activity was tied to what they learned about light and shadow through the construction of the shadow puppets and to the *NGSS* first-grade performance expectation 1-PS4-3: Plan and conduct investigations to determine the effect of placing objects made with different materials in the path of a beam of light.

Throughout the quarter, they engaged in other activities related to maker education including creating cardboard automata, building robots, sculpting circuits made of conductive clay, and designing objects to be printed with a 3D printer. Reflections following each activity focused on connections to the *NGSS* and how to assess whether or not students were learning without disrupting the maker experience.

The culminating assignment was to develop and facilitate an activity at a School Maker Faire (Table 1). The preservice teachers worked in small groups to iteratively design the activity they would facilitate both in their stu-

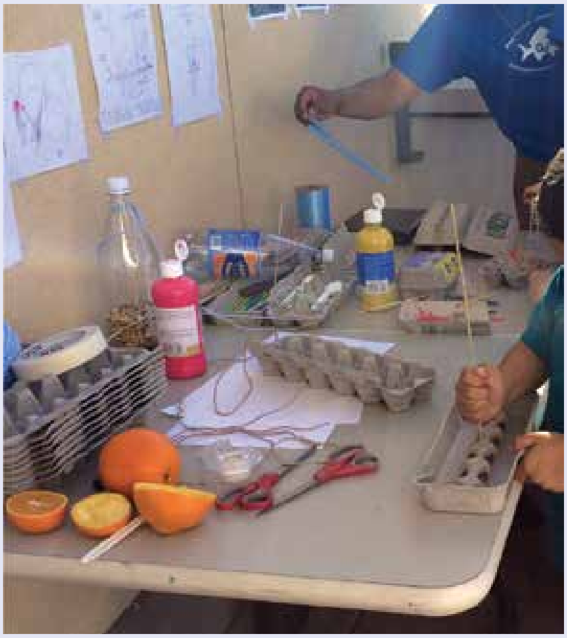
TABLE 1. (continued)

School Maker Faire activities.

Preservice Teacher Stations	Description	*NGSS* Alignment
Recycled boats	Students will be given an assortment of materials to create something that floats. Students will be assigned the task of creating something that floats using at least three materials.	K-2-ETS1-1; K-2-ETS1-2; 3-5-ETS1-1; 3-5-ETS1-2
Balloon rockets	Students will be in groups of 2–4 and will make balloon-powered rockets. They will be experimenting to see if the rocket goes farther with a bigger or smaller balloon. They will test different designs and make observations on how the size of the balloon correlates to how far the rocket traveled.	K-2-ETS1-3; DCI: ETS1.C
Squishy circuits	Make circuits using Play-Doh.	4-PS3-2
Stomp rockets	Students will work in groups or individually to create stomp rockets, use their scientific knowledge to classify different rockets, and which ones will go higher than others, then develop hypotheses about which rocket will go highest and back up their claim with evidence.	3-PS2-1
Car racing	The first step to the process is for students to draw a model of their design. When they have created their design, participants will construct “cars” from bins of Legos, and will then race their cars down a ramp. The participants will try to make the fastest car, and can re-engineer and tinker with their designs when they have another turn. A race will take place every 10 minutes. Each step must be completed, so each racer will have illustrated their design, then built their model. Students can make changes to their original illustrations.	ETS1.A; 3-5ETS1-2; K-2-ETS1-2; K-2-ETS1-3; Crosscutting Concept: Energy & Matter, Patterns, Cause & Effect

FIGURE 1.

Children create bird feeders.



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dent teaching placement and at the School Maker Faire. They also developed an assessment activity and rubric designed to elicit student ideas and measure conceptual development of *NGSS*-aligned content related to their maker activity. The preservice teachers could either assess the students in their student teaching classroom placement or they could assess students at the School Maker Faire. The instructor and teaching assistant provided feedback on early drafts on criteria such as whether the assessment was likely to elicit the goals, whether the associated rubric showed conceptual growth, and whether the activity, learning goals, assessment, and rubric were aligned. We encouraged the preservice teachers to think beyond multiple-choice tests and to develop assessment tasks that did not distract from the fun of the maker activity and suggested using assessments that included design drawings and journals, using the artifact as evidence of learning, or informal interview questions. Two weeks prior to the School Maker Faire, the preservice teachers hosted a "mock maker faire" in their science methods course. They set up their activity and took turns facilitating their activity for their classmates and providing feedback to their peers.

The School Maker Faire

At the School Maker Faire, stations were set up in classrooms and lawn spaces around the university education building where the preservice teachers took classes. Additional classrooms were used for workshops on computer programming and 3-D printing, as well as a panel discussion featuring local elementary school teachers who were already integrating maker education into their classrooms.

Three to five maker activities were placed in each classroom, loosely thematically grouped. One room focused on "remixing everyday materials" and housed four stations: building boats out of recycled materials and testing how many pennies the boat could hold, building balloon rockets out of balloons and toilet paper rolls, and lunar landers built out of paper plates and cups to hold a marshmallow "astronaut." Outside this room, students designed and built bird feeders. Another classroom housed "Electricity, Light, and Color" stations, and a third housed "Materials and Art." Online, we have shared the activities planned and facilitated by the preservice teachers, the descriptions provided by the preservice teachers for the visitors, and the *NGSS* alignment they identified (performance expec-

The *NGSS*, Engineering, and the Challenge for Elementary Schools

The *Next Generation Science Standards* (*NGSS*) describe a vision of science in which children learn science through the practices of science and engineering. Engineering design is included in disciplinary core ideas, as part of the practices, and integrated into performance expectations at all grade levels. Integrating engineering into science instruction will be challenging for U.S. elementary teachers to implement, especially in ways that will broaden diverse students' participation in these disciplines. One strategy is to look to the growing Maker Movement for inspiration. While making and engineering are not identical, they are related in that by engaging in making, students are often also engaging in engineering design (Martinez and Stager 2013).

Effectively integrating maker education opportunities into schools requires educators to balance the demands of formal school with goals of the Maker Movement, particularly in assessing maker education (Halverson and Sheridan 2014). This means creating activities that align with the goals of maker education while also facilitating learning standards and curricular goals for which schools are held accountable—all without reducing maker education to only a focus on the tools (Martin 2015) or only creating small projects like key chains (Blikstein 2013).

tations, DCI, practices, crosscutting concepts or a combination of all three [see NSTA Connection and Table 1]).

Local elementary school children and their families were invited and over 400 guests attended. At the event, families were free to wander to any station and to stay for as long or as little as they wanted. This required the preservice teachers to think about how to design activities that invited children to engage with the materials. Also, because this included children from kindergarten through sixth-grade classrooms and their siblings, the preservice teachers might encounter a 5-year old, a 10-year-old, and parents simultaneously, requiring the preservice teachers to provide multiple entry points to the activity. Further, the children created very different artifacts and interacted with the content in multiple ways, highlighting the diversity of student ideas. To provide a sense of the types of activities planned by the preservice teachers, a subset of the activities are described in the following section.

Example 1: Bird Feeders. Three preservice teachers designed a station in which children learned about local birds through posters displayed around their station. These posters included images of the birds and information about the birds' size, food source, and typical habitat as well as information about how pollution was impacting the habitats of local birds. Children were provided with recycled materials and challenged to build a bird feeder that would meet the needs of one specific, local bird species (see Figure 1). At the station, children were asked to draw out their ideas before building (see Figure 2). The preservice teachers asked students questions about how the design accounted for the weight of the bird, whether it would allow the bird's beak to fit, and whether the seeds would fall out when it was hanging. These preservice teachers aligned their station to engineering (K-ESS3-3, K-2-ET1-2) and life science performance expectations (3-LS4-4). In a reflection after the event, the preservice teachers stated that they knew that students were learning science and engineering at their station because, "Students were able to sketch, create, and test their feeder. This allowed students to use critical thinking skills to design a practical feeding instrument. Students came to the station and the first thing they were asked was to sketch a model of what they wanted to make. Then they chose what material they wanted to construct the feeder from." The preservice teachers used these drawn models to probe the students' understanding about birds.

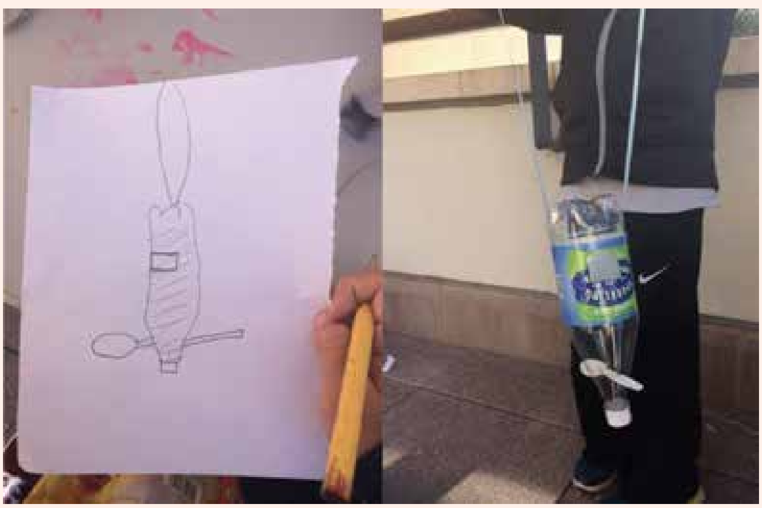
Example 2: Make a Game Controller or Music Player. At another station, families experimented with everyday materials to make a game controller or music player. The station included three computers set up with a piano keyboard program (see Figure 3), a video game, and an open programming Scratch screen (*scratch.mit.edu*). Each computer was connected to a device that mapped to the keyboard, activating particular keys when a circuit was completed. The content goal for this station was focused on completing a circuit. In the accompanying assessment activity, the preservice teachers asked students in their classrooms to make a controller for an online Simon game, which communicated with the player using light and sound (NGSS 1-PS4-4). The children then drew their circuits and explained their reasoning.

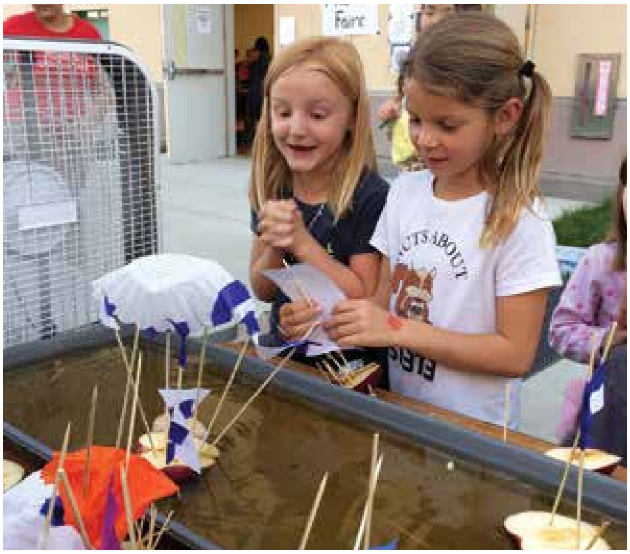
Example 3: Balloon Rockets. A third station focused on balloon rockets in which children used balloons, toilet

A child made a game controller using modeling clay.

FIGURE 2.

Child's drawing (left) and bird feeder (right).





Students test boats made of apple pieces.

paper tubes, and straws to design a rocket. They placed the rocket on string and observed how it moved when the air was released from the balloon. These preservice teachers described observing children designing and testing their balloons to assess their understanding of engineering (NGSS K-2-ETS1-3) and physical science (K-PS2-2) performance expectations and related practices (analyzing and interpreting data) and disciplinary core ideas (ETS1.C). For example, simply placing the rocket in the correct direction on the string indicated some level of understanding of how the balloon would move when the air was released. For example, in response to the question about how they knew children were learning, one preservice teacher at this station stated, "I know students were learning because they were adjusting what they were doing based on what they observed. If they faced the rocket the wrong way, they would turn it around for the next trial. They would notice that their rocket didn't make it to the end of the string and decide it was too heavy and some parts needed to be removed. Their answers to our questions were also developing as they tested ideas and gained more experience." These preservice teachers designed a separate activity to run in their classroom to create a more focused opportunity for assessment. In the classroom, they created stations focused on different topics. At one station, children designed rockets, drew ideas, and tested rockets. At another station, children compared two different rocket designs and made predictions about how well they would work and supported their predictions with evidence from earlier trials. This activity both allowed for open-ended design and focused assessment activities.

After the Event

After the event, the preservice teachers submitted reflections on the event. They were asked how they knew if students were learning, what they as facilitators learned from the event, and what surprised them. Recurring themes were that the preservice teachers were surprised by how capable the children were, how much the children enjoyed the activities, and the diversity of children's ideas. One preservice teacher who facilitated a station on squishy circuits stated, "We learned that regardless of age, kids are able to engineer complex things with the appropriate help of an adult. It was great to see the kids working hard to understand why it wasn't lighting up."

Moreover, the preservice teachers enjoyed themselves and found that they learned engineering and science along with the children. As one stated, "I learned that it is possible to teach what can be a complex science lesson to kids of all ages. It was fun to challenge myself in finding the right way to teach kids who were 5 and kids who were in fifth grade the same essential thing. I also found that through explaining it over and over again to different students I was even building on my understanding of the engineering concepts that I was explaining to the students." Another described, "I loved to see students guiding their own learning through their reactions and choices. We had questions to facilitate the learning, but letting the kids lead always added new directions and brought up new opportunities. This was such a fun way to teach and learn!"

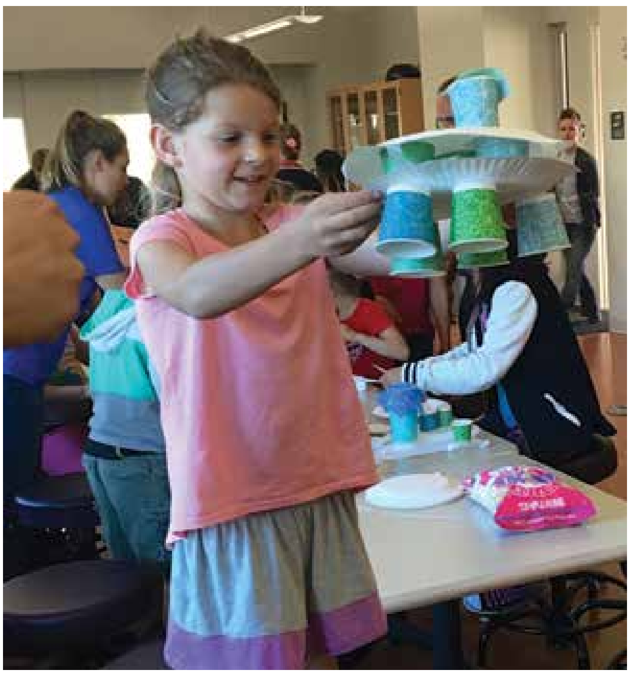
FIGURE 3.

A family creates a music player using fruit.

How This School Maker Faire Fits Into Larger Maker Movement

The stations designed by the preservice teachers each set up a specific challenge and included specific materials. None of the stations provided step-by-step instructions. Instead, the preservice teachers were interested in what the children would choose to build within the constraints of the tasks and the children's design process and decisions. However, none of the projects provided the visitors a chance to decide what they wanted to build themselves. Personal relevance is a hallmark of maker education and many Maker Faires include areas for open-ended building. This was discussed in the course; however, because the preservice teachers were also expected to demonstrate competency in their understanding of *NGSS* and science instruction, an open-ended station that also met the constraints of their assignment would have been more difficult to design.

In a reflection after the Maker Faire, multiple preservice teachers reported that their station became less structured as they interacted with more children. In some cases this was because they found that, when they had multiple ages at the same time, they had to be more flexible in their expectations. In other cases, it was because their station was near another station that used different materials and students began productively using other materials in unexpected ways. In the future, we will partner with other facilitators to include such stations at the School Maker Faire so that the event exposes the teachers (and participating children) to a wider range of experiences typical at a Maker Faire yet still allows the preservice teachers to practice designing an activity that meets goals of *NGSS* and is assessable.



A lunar lander protects its marshmallow astronaut.

Conclusion

In addition to the preservice teachers participating in the course, the School Maker Faire also served local practicing teachers. Many local teachers attended to learn about maker education and some of these teachers have already replicated the event at their own elementary school or integrated maker education into the regular school day through initiating the construction or designation of makerspaces in their schools.

As the preservice teachers who participated in this event take jobs in schools and have their own classrooms, they will be prepared to harness the enthusiasm and creativity of maker education and help children develop understandings of disciplinary core ideas, science and engineering practices, and the crosscutting concepts of the *NGSS*. ■

Danielle Harlow* (dharlow@education.ucsb.edu) *is an associate professor and Alexandria Hansen is a PhD candidate, both at the University of California, Santa Barbara.

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NSTA Connection

Download descriptions of how these activities connected to the *NGSS*, plus the assignment overview and a list of helpful resources, at *www.nsta.org/SC1803*.

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

Performance Expectation	**Connections to Classroom Activity** *Preservice teachers*:
1-PS4-3. Plan and conduct investigations to determine the effect of placing objects made with different materials in the path of a beam of light.	• experimented with light and shadow to create shadow puppets that had different effects.
Science and Engineering Practices	
Asking Questions and Defining Problems	• developed activities for children that defined problems for children to solve. (Note: This does not engage the children in the practice of defining problems, but does provide the preservice teachers with the experience of defining problems.)
Developing and Using Models	• created models and prototypes related to various design challenges in the class. They also were encouraged to collect students' drawn or constructed models to use as part of their assessment activity.
Constructing Explanations and Designing Solutions	• used students' final designs as assessment tools.
Disciplinary Core Ideas	
3-5-ETS1-1: Engineering Design: Define a simple design problem reflecting a need or want that includes specified criteria for success and constraints on materials, time, or costs.	• engaged in defining a simple design problem in both their construction of an activity for children. They were instructed to think of the School Maker Faire activity as a design problem. They had specific constraints (space, time, materials) and goals related to children's learning. • engaged in this DCI through engineering activities in class. For example, they discussed an engineering challenge proposed by NASA to design a non-edible food-related object that could be 3D printed by astronauts (*www.futureengineers.org/startrek*). They identified constraints related to conditions of outer space, size, and material constraints as well as the specific problems that needed to be solved.
3-5-ETS1-2: Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.	• brainstormed multiple ideas for their School Maker Faire activity. They then discussed which would be most likely to be effective in the specific setting and with multiple age levels. • included stages in class engineering activities where students developed multiple possible solutions.
3-5-ETS1-3: Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.	• included stages in class engineering activities where preservice teachers tested multiple models to identify how a prototype could be improved. In one example, they were tasked with replicating the actions of a cardboard automata (an object that when a lever is rotated, other objects move up and down, side to side, or around [*http://tinkering.exploratorium.edu/cardboard-automata*]). The interior mechanisms of the sample automata were hidden from the preservice teachers. They constructed and tested multiple models to determine which best recreated the desired actions.
Crosscutting Concepts	
Cause and Effect	• engaged in activities where they explored how changing one aspect changed another.
Systems and System Models	• engaged children in constructing models of systems and identifying the specific components.
Structure and Function	• considered the structure and function of the objects they designed and the objects that children designed.