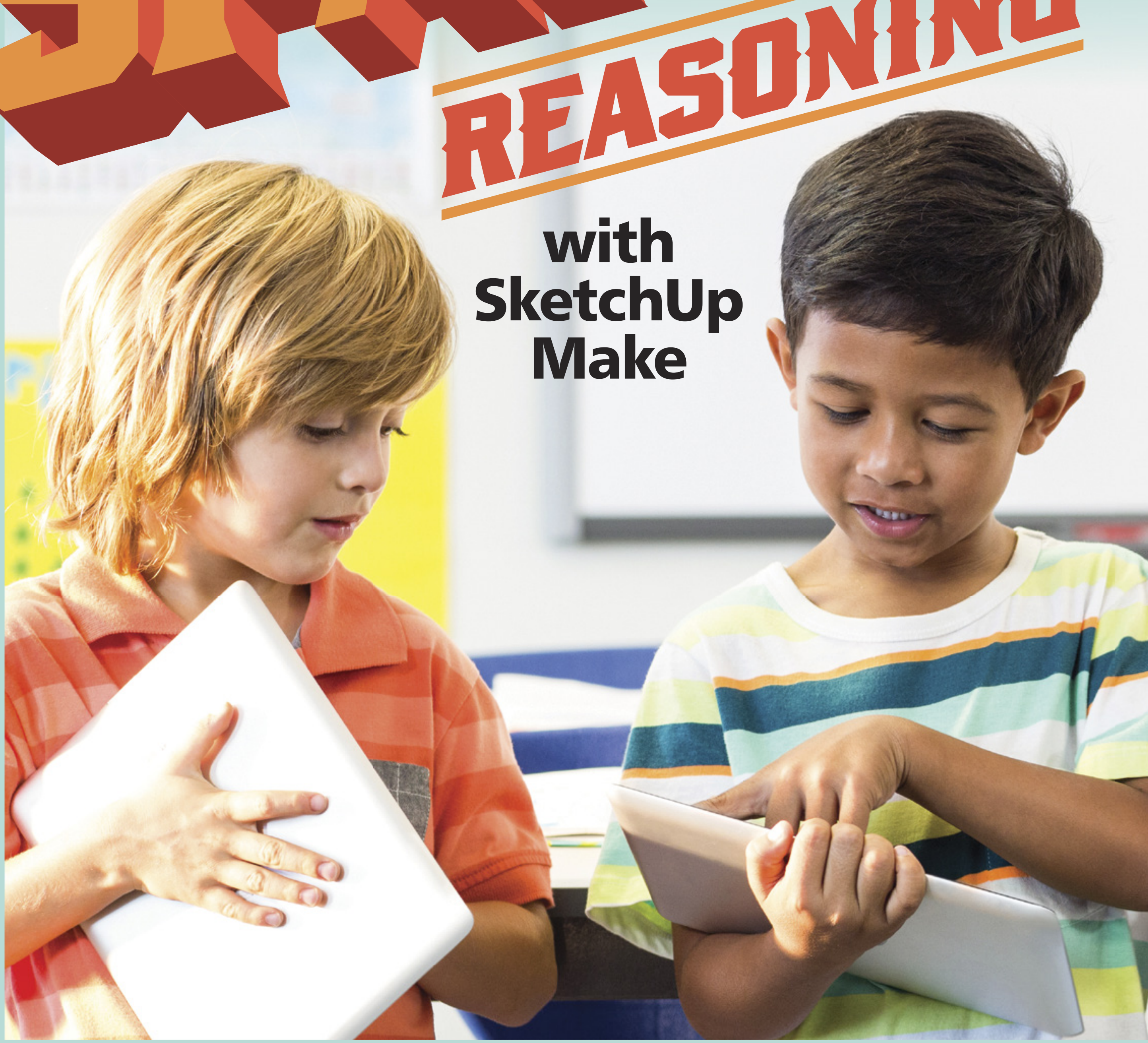
Exploring Spatial Reasoning with SketchUp Make



WAVEBREAKMEDIA (CHILDREN); NREY (LETTERING)/THINKSTOCK

Kindergartners created representations of real-life objects in three dimensions as well as 3D representations of MagnaTile objects, giving them a unique experience with technology and furthering their knowledge of 3D shapes.

Bethany Singer and Kathryn G. Shafer

Building physical models is a natural activity for children and provides a context for lessons on two-dimensional (2D) and three-dimensional (3D) shapes. However, children do not think of their models as prisms, cylinders, and pyramids. Their creations are spaceships, tunnels, castles, and nets on the floor. Creating these types of shapes with SketchUp Make™ (Trimble Navigation)—a widely popular program with architects, video game designers, model builders, and digital printing enthusiasts—helps students as young as five and six years old gain meaningful experiences with two-dimensional and three-dimensional shapes. Identification of shapes, as well as modeling through building and drawing, are specifically addressed in the Common Core State Standards for Mathematics (CCSSM) K.G.A.3 and K.G.B.5 (CCSSI 2010).

Identifying and modeling shapes, especially in three dimensions, requires spatial reasoning, which is formally introduced in school curricula and standards as early as kindergarten (Schroeder, Lee, and Mohr-Schroeder 2016). Engagement with the SketchUp Make program fosters experimentation in a spatially accurate virtual world that provides immediate feedback with each click or drag motion of the mouse. We posit that as students work within the SketchUp program, they actively explore mathematical relationships that are also embedded in the use of physical manipulatives (NCTM 2014).

In what follows, author Bethany Singer describes and reflects on a sequence of SketchUp activities that she designed and implemented in 2014 at a developmental kindergarten (DK)-4th school located in the Midwest. In 2013–2014, this school had 550 students, with approximately 23 percent receiving free and reduced lunch. Singer had most recently taught algebra and geometry to students in grades 7 and 8 before moving to the kindergarten level.

My goal for kindergarten students is to identify two-dimensional shapes and three-dimensional solids. I also want students to use accurate vocabulary when discussing and creating models. During the school year, my students use MagnaTiles™ during math centers to form nets and solids using square, rectangular, and triangular tiles (see **figs. 1a** and **1b**). Throughout three SketchUp activities—introduction, free play, and modeling—students learned the definitions of the terms *two-dimensional, three-dimensional, faces, vertices,* and *edges*.

FIGURE 1

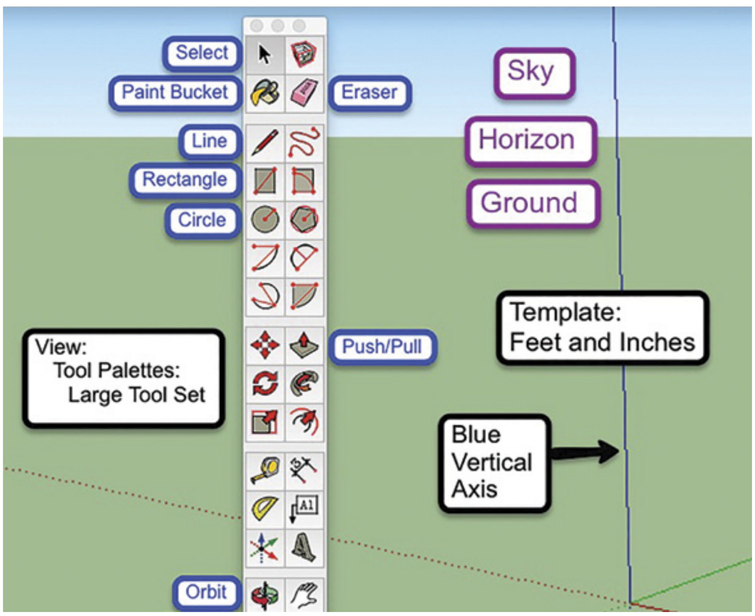
During a typical academic year, Singer's students use MagnaTiles in math centers to form nets and solids using square, rectangular, and triangular tiles.

(a) This student created a castle.

(b) Two students worked on forming a net for a MagnaTile creation.

FIGURE 2

This SketchUp screenshot shows the Large Tool Set in the Feet and Inches template.



Introduction to SketchUp

The fifteen-minute introduction to SketchUp took place in the classroom as I projected my computer screen on the whiteboard. I demonstrated four basic tools: rectangle, push/pull, orbit, and eraser. I showed the class how to click on the icons to switch from one tool to the next, and then I drew a couple of rectangles and "pulled" them out of the plane. I explained how pulling a rectangle up changed the two-dimensional shape into a three-dimensional prism. Then I used the orbit tool to dynamically rotate the prism and visualize all three dimensions of the model. I also demonstrated how to use the eraser tool so that students would be comfortable fixing any mistakes they might make in their constructions. Students found the draw, circle, and paint tools during the free exploration and modeling activities (discussed below). Instead of using the icons on the horizontal tool ribbon, students used the vertically oriented Large Tool Set, which is found in Tool Palettes under the View menu (see **fig. 2**).

Free exploration

The day after the whole-group introduction, the class went to the computer lab to use the technology. During this initial thirty-minute session, I did not give the kindergartners a specific task but instead allowed them to independently explore the software by creating shapes and solids without prompts. I chose this exploration time for two reasons. First, I was unsure what students would be capable of doing with the program; and second, I did not want to limit their creative abilities. This approach also allowed me the time to spend with each student, discussing his or her creation and introducing the appropriate geometry vocabulary to help students describe what was on their screen.

When the user first opens the Feet and Inches template, the figure of a person appears close to the origin. This 2D graphic helps the user differentiate the ground (green) from the sky (blue). When I personally work in SketchUp, the first thing I do is to remove the figure by selecting it and hitting the delete key. In 2014, the figure

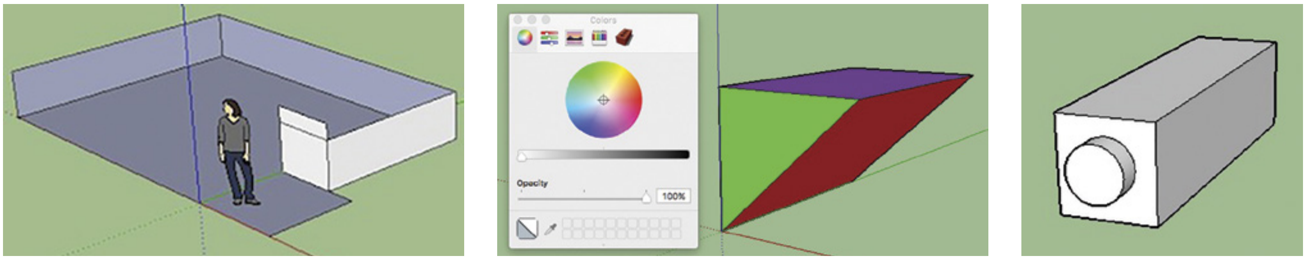
FIGURE 3

Unlike an adult who deletes the figure of "Susan," students integrated her into their drawings and used her as a reference point.

(a) A student worked on creating a house for Susan.

(b) Tina explored with the paint tool on a triangular prism that she created.

(c) A third student created a Lego™ piece.



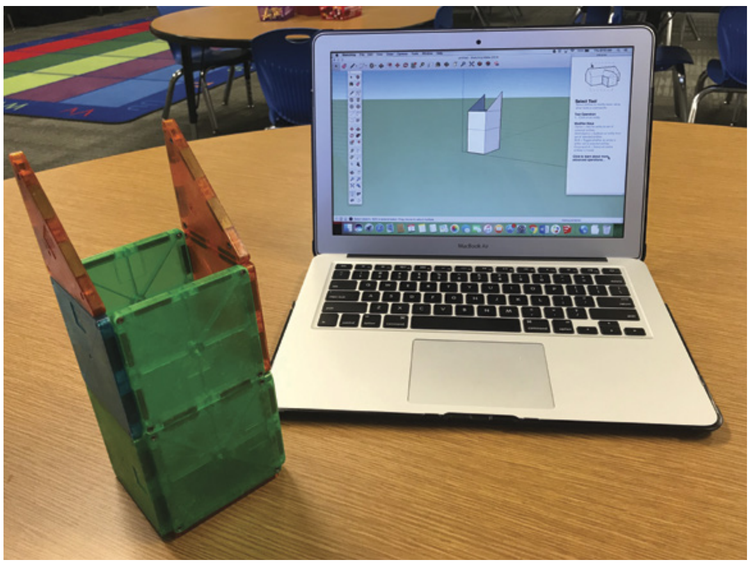
near the origin was a woman. Instead of deleting the figure, my kindergartners wanted to know her name, which is Susan. The students integrated her into their drawings and used her as a reference point. A popular exploration was to create a variety of buildings, such as houses and castles. Throughout these investigations, about half of the twenty-six students worked on putting walls around Susan (see **fig. 3a**).

As soon as students began working with the program, they started exploring tools that I had not introduced. They quickly discovered and used the circle tool to create cylinders, the paint tool to change the color of a surface, and the draw tool to integrate the shapes. Tina created a triangular prism using the draw and push/pull tool and then colored the prism's faces with the paint tool (see **fig. 3b**) so that her model would look like the MagnaTiles that she played with in our classroom.

While I was watching students explore, I found it interesting that most of the objects students created had real-life connections. For example, one of the boys decided that he would create Legos™ on his screen by using the rectangle and circle tools as well as the push/pull tool (see **fig. 3c**).

FIGURE 4

Some students created a rectangular prism with MagnaTiles. Using the rectangle and push/pull tools, they re-created the physical model in SketchUp and drew a line on the rectangular faces of the prism to see that two square tiles make up the side.



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Creating physical and virtual models

For the third activity with SketchUp, I created a structured task that would foster a connection between physical objects and the computer models (NCTM 2014). One week after the free play activity with SketchUp, I modeled to the whole class how to build a rectangular prism with MagnaTiles and then how to use the rectangle and push/pull tools to re-create the physical model in SketchUp. I also showed students how to draw a line on the rectangular faces of the prism so they could see that the side was really made with two square tiles (see **fig. 4**). Students then used MagnaTiles to create their own physical models of prisms, cubes, or other 3D objects, and then they carried these objects to the computer lab.

My expectations were for them to create cubes and prisms using the tiles and then to attempt to re-create these on the computer screen. The students exceeded my expectations with their abilities to represent their object using SketchUp. Twelve of the kindergartners who finished quickly used the paint tool to add the colors of the tiles that they used so that they had an exact replica. Some students created very complex objects and discovered how to use the draw tool to make triangles extending up from the prism in SketchUp.

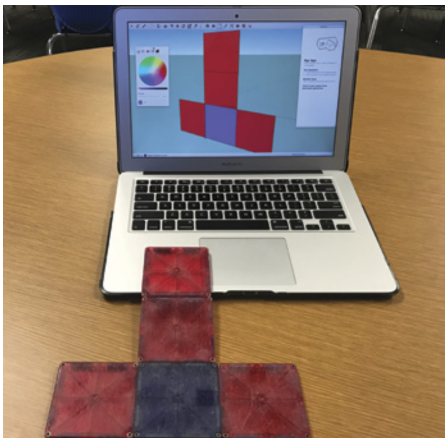
Students also explored their models with the orbit tool to make sure that each side of the prism was an exact replica. When Tristan and Jacob finished with the representation of their objects in SketchUp, they worked on making a net for their object by deconstructing the MagnaTile object (see **fig. 5**).

Connections

A few weeks after using SketchUp, my students surprised me when they transferred this knowledge from the technology setting to a hands-on experience within the classroom. While completing a two-dimensional shape-sort activity—to introduce a rhombus, parallelogram, and hexagon—my students informed the substitute teacher that the pattern blocks she was using were three-dimensional. Students reasoned that the pieces were 3D because they were thick; the hexagon had eight sides. Students were visualizing the action of pulling the hexagon up out of the plane, and they used spatial reasoning to count the total number of faces. The substitute teacher ended up tracing the pattern blocks onto paper so that students would accept that she was teaching them about two-dimensional shapes. This class discussion illustrates Common Core State Standard K.G.A.3: *Identify shapes as two-dimensional* (*lying in a plane, "flat"*) *or three dimensional* (*"solid"*).

FIGURE 5

Tristan's net of MagnaTiles lay flat on the desk. The net is represented in SketchUp.



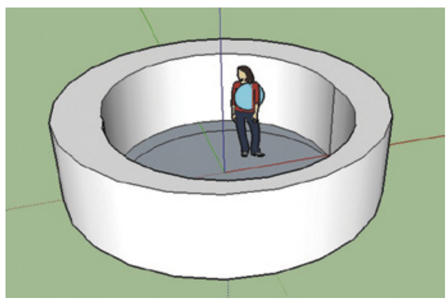
Throughout the free exploration and creative modeling activities, I asked my students about their models. Each student described his or her creation with great detail; students explained exactly which tools they used and how they made their 3D objects. The majority of their explanations included a real-life connection about what they were creating in SketchUp. They also explained the difference between 2D and 3D shapes by demonstrating with the push/pull tool. These individual discussions illustrate Common Core State Standard K.G.A.5: *Model shapes in the world by building shapes from components and drawing shapes.*

At the end of the school year, Dr. Kathy Shafer visited my classroom during a session of SketchUp free play in the computer lab. What did we observe? Students used the circle tool a lot. They drew concentric circles to create rings, which they then extruded to create wells and tunnels. Often students strategically created these cylindrical shapes around Susan (see **fig. 6**) or drew them on the faces of prisms to make columns and tubes.

When working with young children, we often have to ask, "What did you make?" This is true with both physical and virtual objects. For example, what appeared to us as random lines drawn in space and a few painted surfaces was actually a submarine with a tent inside. In fact, if time is short, we encourage teachers to stress individual free play over a structured task that will limit students' creativity. We also encourage teachers to use SketchUp with students needing accommodations. For example, Jared had some significant fine-motor delays, which made holding a pencil difficult and drawing or writing that much harder. With SketchUp, he manipulated

FIGURE 6

A student put Susan in a well.



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the mouse in broader motions and was able to create a playground using the draw tool and the rectangle tool (see **fig. 7**). He proudly explained which rectangles represented the slide and swings and the location of a road. SketchUp is a technology that can be adapted for students of all ages and can easily be integrated into the instruction of multiple math standards.

Limitations and challenges

Throughout these activities, I expected to encounter some challenges with my kindergarten students working with the SketchUp program. However, the greatest challenge was taking the time to get twenty-six students logged in to the computer lab, finding the right keys to type, and getting the correct passwords entered. On our computer days, three parent volunteers logged in the students, opened the program, and made sure the large vertical tool bar was open on the screen. Once this was done, the parent volunteers talked to individual students about what they were making.

I observed an interesting phenomenon with a few students who were quite familiar with touch-screen devices. They attempted to orbit their shape by touching the computer screen instead of using the mouse. Other than the issues of getting started in the lab and introducing the use of a mouse to a few students, the actual activities were so exploration-based and student-centered that students had no real limitations or challenges. This is a "low floor, high ceiling" task in which students can continually extend their own learning without feeling frustrated about the task.

Reflection

Through the use of SketchUp, the kindergartners actively engaged in the Common Core's Standards of Mathematical Practice to *attend to precision* (SMP 6) *and use appropriate tools strategically* (SMP 5). Students were extremely precise in their drawings, so the virtual shapes matched a MagnaTile creation or a real-life object. The children quickly drew rectangles and circles, pulled them out of the plane to make objects, and changed perspective with the orbit tool to add color to a surface or continue creating their model.

I also noticed instances of spatial reasoning that one would not expect from kindergartners. Although some shapes and solids were built on the ground (at the horizon), in many cases, the surfaces and solids appeared to float in space.

FIGURE 7

Jared represented a playground.

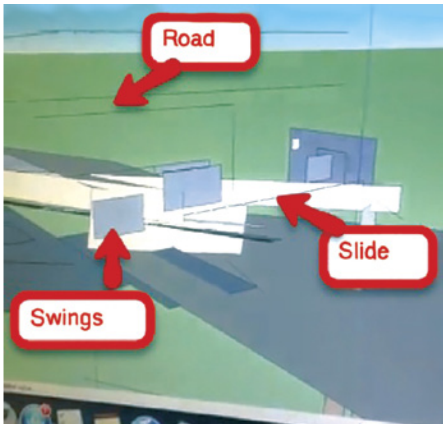
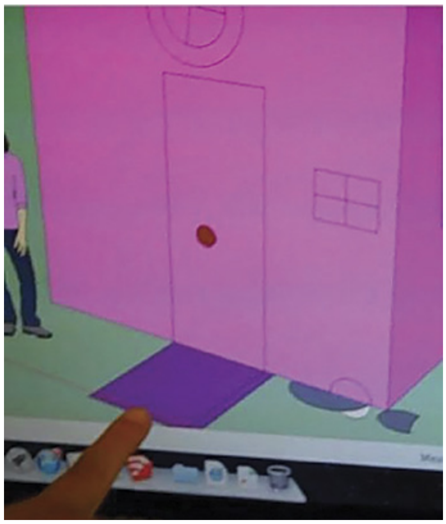


FIGURE 8

The adults observed simple prisms and sophisticated, detailed buildings like this house with a shoe mat.



A student who built a town at the origin focused on the intersection of the three axes to find his town as he zoomed in and out. He indicated that his town was a point when he zoomed way out, and then he brought the buildings into view by zooming in. He also showed us that he could "go inside" a building, which is possible with this program.

We feel that this type of interaction with SketchUp mimicked students' play with the MagnaTiles but allowed even more freedom because students were not limited to specific tile shapes. Just as making houses is popular with hands-on tools, it was also a popular activity in SketchUp. We observed simple prisms as

FIGURE 9

In the most advanced used of SketchUp that we witnessed, Kayla drew a hat on Susan and used the eraser tool to redraw arcs until she had represented parts of Susan's necklace precisely on the screen.

well as sophisticated buildings that included doors, windows, chimneys, and even a shoe mat (see **fig. 8**). Some of the houses were created by extruding a rectangle; others were created around Susan with three walls, a floor, and a flat roof for a dollhouse effect. When students have the chance to explore and create on their own, they can be precise about what they are building and analyze exactly which tools will work the best, especially so that their designs will replicate the real world. We saw the most advanced use of SketchUp when Kayla used the arc tool to draw a set of necklaces around Susan's neck (see **fig. 9**). Using the eraser tool, Kayla redrew arcs until she had precisely represented parts of the necklace on the screen.

We encourage teachers of all grade levels to consider using SketchUp as a tool for teaching and learning mathematics. Think about 2D lessons on tessellations or nets (recall Tristan and Jacob) by using the 2D top view. Contemplate having groups of students find the volume and surface area of objects with different templates (inches, feet, millimeters, or meters) to foster discussion on unit conversions or rounding errors. Whatever your specific need may be at your grade level, we have learned through this process that by investigating with new technologies integrated into lessons, students will reach a much greater depth of knowledge than you would imagine. We learned quickly to never underestimate what students can do or will try to do with a newly introduced technology.

Common Core Connections

K.G.A.3	SMP 5
K.G.B.5	SMP 6

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***Authors' note:** In 1999, Last Software of Boulder, Colorado, developed SketchUp. In 2012, Google purchased the program and renamed it Google SketchUp. In 2014, the program was purchased by Trimble Navigation and renamed SketchUp Make. Trimble Navigation offers an advanced version of SketchUp to educators and students free or at a reduced price; however, we think the tools available in SketchUp Make are more than sufficient for K–grade 12 classroom.*

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