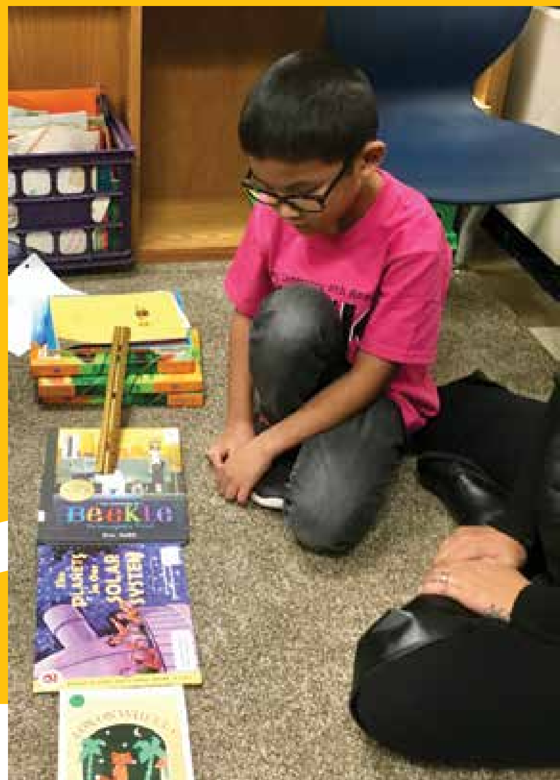
JUST ROLL WITH IT



Students use a ramp to see how a marble travels.

Incorporating engineering into third-grade science

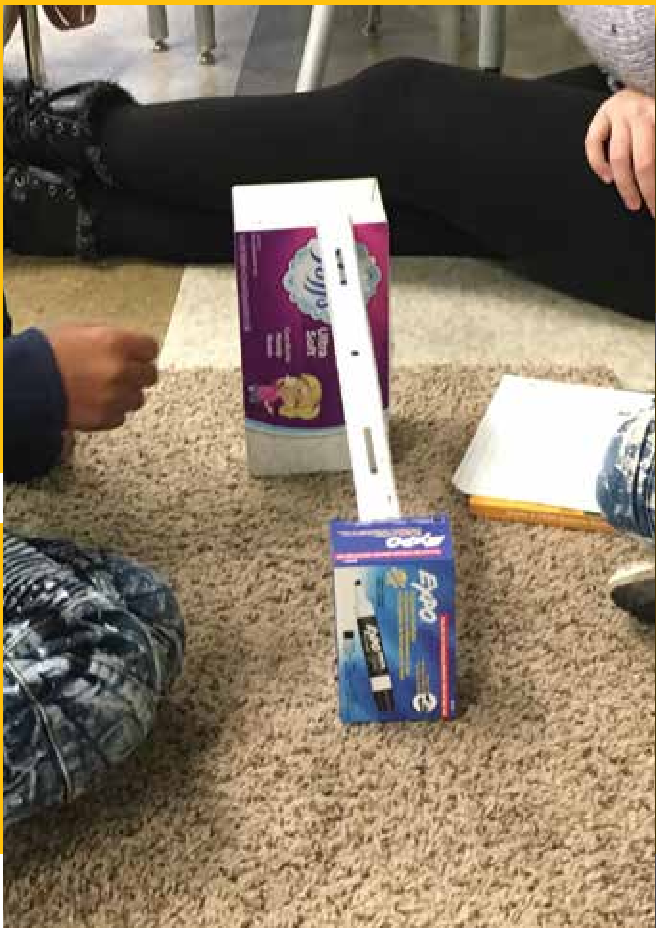
By Jordan Holub, Jerrid Kruse, and Lucas Menke

Science and engineering practices are a major aspect of the *Next Generation Science Standards*. Teachers can "pique students' curiosity, capture their interest, and motivate their continued study; the insights thus gained help them recognize that the work of scientists and engineers is a creative endeavor" (Appendix F, NGSS Lead States 2013, p. 2). Unfortunately, engineering is portrayed as a step-by-step venture. However, "[l]ike the methods of science, engineering and design processes do not follow the same steps every time. They run into roadblocks, causing engineers to creatively pursue many possible paths as they work" (Kruse et al. 2017, p. 40).

In this article, we focus on students constructing observations of patterns to understand how surfaces affect the motion of an object. Students will use the patterns they observe to predict future motion of marbles (NGSS Lead States 2013). Students then apply their learning by engaging in an engineering task. By giving students a task to enhance their designs by controlling specific variables, we can incorporate engineering practices into the lesson (NGSS Lead States 2013). To extend learning, we draw students' attention to the nature of engineering (NOE) throughout the lesson.

Day 1: Exploring Rolling Surface

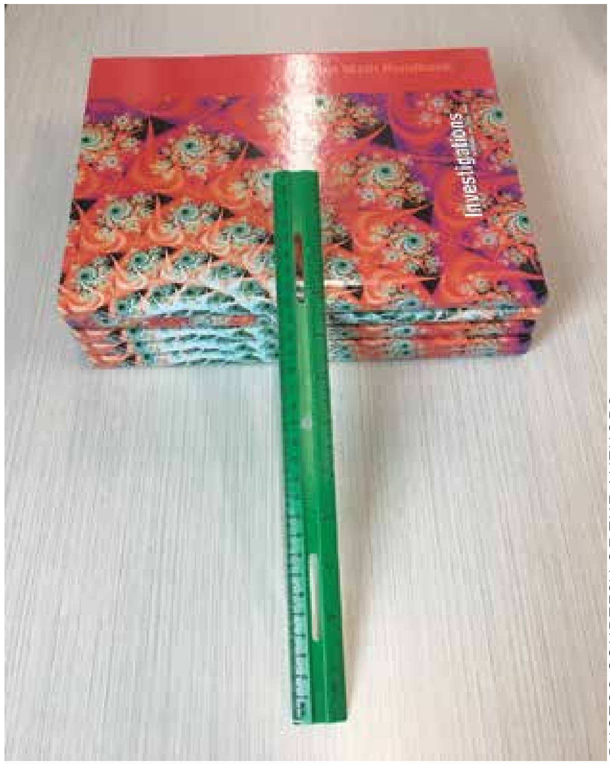
While showing students a marble, we ask, "If you were to roll this marble across the floor, how far do you think it will go?" Students give a range of answers. When one student states, "It depends on the type of surface the marble is on," we ask the class for some ideas related to how the surface might affect the rolling distance. After students share some ideas, and we acknowledge but do not confirm or deny the answers, we ask, "How could we get the marble moving across the floor?" Students suggest rolling or pushing the marble on the ground. While we like having students make decisions during their investigations, they need a little guidance, so we show them the setup in Figure 1. We ask, "How could we use this ramp to see how a marble travels?" One student suggested that it would push the marble down. We then asked, "How could we roll a marble to get consistent results?" A student shared that we could drop the marble from the same spot. We reinforce that they should only "let go and not push" the marble at this point. We want stu-



Students use different materials to adjust the ramp's height.

FIGURE 1

Ramp setup.



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dents to understand that their "launch" spot should be the same each time for more consistent results during their investigation. Many students chose to drop their marble approximately an inch below the top of the ramp to ensure that the ramp doesn't move during launch.

Next, we ask students, "How could you measure how far your marble travels?" Students gave both standard (e.g., inches) and nonstandard (e.g., finger lengths) units. Depending on your students, either approach will work. Then we ask, "How will you record your measurements?" We have students collaborate with their table groups for ideas on how to record their results. Students typically create a table or T-chart where they can write the surface and the distance next to each other. We write a couple of examples on the whiteboard so students have an idea of how to record their data.

We remind students of our task by stating, "We made some predictions about how the surface will affect how far the marble rolls. Now that we can launch the marble consistently, how could we test our ideas?" One student shared, "We could use different types of floors." We then asked what different types of floors were in the school. After students share their ideas, we suggest using three different types of surfaces. Our class chose to launch our marbles on tile, cement, and carpet. For differentiation purposes, students can use classroom tables to do the investigation. Teachers can substitute a table for the tiled hallway, sandpaper for cement, and a towel or some thick fabric for rug/carpet. Students will still get very similar results. We have students work in groups of two or three for the investigation based off mixed ability levels and compatibility. Helping students set up the investigation takes around 15 minutes. While we could do this faster with explicit directions, we want students to understand what they will be doing and why.

We start our investigation by going to the tiled hallway. We spend about 10 minutes at each location. We use a grooved ruler coming down from four stacked textbooks as our ruler (see Figure 1). Students decide who will launch the marble and who will measure and record the results. The students release their marble and then they measure how far their marble travels. We remind the students to write down their answers. Before launching, we ask students, "Why would we test our results three times?" One student stated, "Scientists want accurate answers so doing it three times helps scientists understand how far the marble will travel." To push students further we ask, "If we have three numbers, which number should we use?" Students usually note that the middle (median) number will be best. This could be an opportunity to address averages, but our students were not yet ready for the math necessary to calculate averages. If one number doesn't fit consistently with the other numbers in the data table, we sometimes discuss with students the idea of outliers. For example, we might ask, "I notice that one of your numbers isn't even close to your other numbers, what do you think happened?" Students sometimes note that something went wrong (e.g., the marble hit something), so we ask, "If we see one number that is way different, why might it be a good idea to redo that test?" Students reply that "the numbers should be close for all the same drops, so if one isn't close, another drop will help you know if it is good or not."

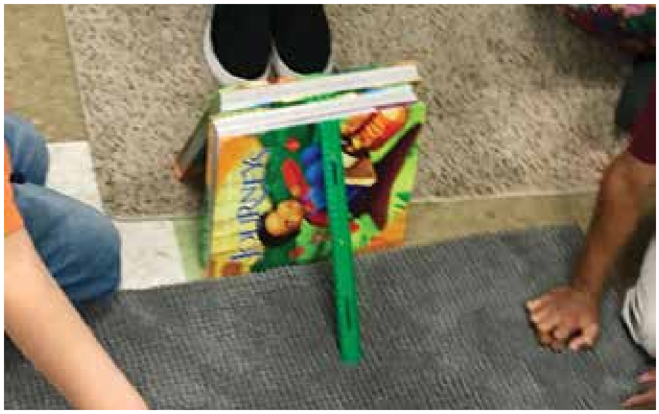
Next we move on to the carpeted classroom using the same ramp design. We state, "We are in a new area, so you will want to record your data again in a new table." Also, students are reminded to label the areas so they will remember where they recorded their results. Students repeat the procedure as they did in the previous floor type. We ask, "How are your results similar or different from our first round?" Students note that the marble does not travel as far as in the hallway. We follow by asking, "Why would our results be different?" One student shared, "The carpet is thick and builds a wall so the marble can't travel as far." Another student shared, "The tiles were smooth which caused the marble to travel further. It only slowed down when it touched the crease in between tiles."

Last, we go outside to the cement by the playground and set up our ramps. Students repeat the procedure and write down their results. Once again, we remind students that we need at least three marble launches.

Once students have finished, we ask them to discuss the similarities and differences that they notice between the three different surfaces they rolled their marbles on. We ask, "What are some things that you notice?" After some small-group discussion, students explained, "The marble went the farthest on the tiles. Our results ranged from 10 finger spaces on the carpet to 216 on the tile, which shows a big difference in marble travel on different surfaces." Our discussion lasts about five minutes, bringing day one to about an hour in total.

Day 2: Developing a Pattern

To draw students' attention to patterns, we ask, "What patterns did you notice between how far the marble went and the kind of surface?" We know that students often learn better when collaborating with peers—"Peer learning has been suggested by many as an educational innovation that can transform students' learning experience" (Blumenfeld et al. 1996). Therefore, we have students discuss with their elbow partners. We come back together and ask for students to share their responses. One student responds, "The marble went the farthest in the hallway." We followed by asking, "Why do you think that occurred?" A student shared, "The floor was the smoothest." We then asked, "Why would that affect the marble?" A student then answered, "The marble didn't have much to stop it."



Students create a steep ramp.

Now we ask students, "What do you notice about the other surfaces?" One student shared, "The marble did not travel very far on the carpet because it built a wall making it so the marble couldn't move as much." To draw students' attention to pattern-making, we ask students to explain how smoothness is related to rolling distance. A student shared, "The smoother the surface, the further the marble went." We then asked, "What happens if the surface is not smooth?" One student said, "The marble would not travel as far because it is being prevented."

The standard we are working with requires students to make predictions based on the patterns they observed. To formatively assess students' predictions, we draw the three surfaces we previously used on the board in order from farthest distance the marble rolled to shortest distance the marble rolled. Then, different surfaces are shown to students and we ask them where they would put it on the board so that the surfaces are still in order of farthest travel distance to shortest. For example, we can show students a thicker carpet square as well as an ice rink and ask them where they would put them on the board. This formative assessment helps us understand whether students can apply the pattern we developed.

To get an idea of individual student understanding, we do a more formal assessment. We ask students the question, "How far do you think the marble would travel on a blanket? Use our investigation to support your answer." We differentiate by allowing students to answer the question by writing, drawing, or explaining their responses verbally. We used a rubric (Figure 2) to assess student understanding of patterns before moving on to engineering the next day. Day 2 discussion and assessment lasts approximately 45 minutes.

Day 3: Assessment Through Engineering

To incorporate engineering into our assessment, we created a task for students to apply the pattern developed in the exploration. After taping an X on the carpet, we ask, "How might

FIGURE 2

Surface pattern rubric.

LEVEL	DESCRIPTION OF LEVEL	EXAMPLE STUDENT RESPONSE
Not Yet Met	Unreasonable response; incoherent answer	"I don't know how far the marble would go."
Developing	Reasonable answer, does not connect to investigation	"The marble would not go very far because the blanket is fuzzy."
Met	Reasonable answer, explanation connects to investigation	"Not very far because the marble traveled the least on the carpet and the blanket is thicker."

FIGURE 3

Summative rubric.

X Challenge Rubric

Level	Description of Level	Example Student Response
Not yet met	Unreasonable set up; no or incoherent explanation	"I don't know why we used wax paper"
Develop ing	Reasonable set up; explanation not related to surface pattern	"We tried to slow down the marble"
Met	Reasonable set up and explanation connected to patterns observed	"We knew the marble was going to go passed the X, so we used something that was rougher than the carpet to slow it down"

ADDITIONAL NOTES:

you get your marble to stop on this X from your location?" Students rattled off different answers. We follow by asking, "What are some problems you will face?" Students share that the carpet will cause the marble to travel a smaller distance. We ask, "What are some ways you can get to the X without changing the distance?" We have students share ideas within their groups and then share with the class. We show students some materials and ask them to discuss with their groups how they might incorporate those materials to help with their task. We provide wax paper, building blocks, textbooks, printer paper, and sandpaper. Then, we have students draw a plan for how they will reach their end goal. Once students draw out their plan, we give them the materials to try out their new plans. It takes students about 10 minutes to make a plan with their groups. Students then test out and modify their plans based on their results for about 20 minutes.

As students finish, we have them write down their reasoning for their final solution and how it worked. During this time we ask students individually, "How were you able to get the marble to the X?" We use a rubric to assess students on their learning (Figure 3). This assessment, which could also be written, allows us to understand if students are understanding surface patterns.

Extending Student Thinking About Engineering

The *NGSS* states, "Students define a problem using criteria for success and constraints or limits of possible solutions. Students research and consider multiple possible solutions to a given problem" (Appendix F, NGSS Lead States 2013). To address this standard, we ask students, "How well did your design work?" To get students to think about the constraints they faced during the activity, we ask, "What things made your task difficult?" One student answered, "The carpet prevented the marble from moving very far so we had to be creative." We use a follow-up question, "How were you creative?" The student responded, "We couldn't change the carpet so we had to use wax paper to help create a smoother surface for the marble to travel." To help students more fully understand the basic principles of engineering, we include the nature of engineering (NOE) into the lesson. While students are working on their X task, or in whole-class discussions, we ask NOE questions such as:

- You just designed a plan to get your marble to the X; why might an engineer make a plan?
- We see that you are collecting data; why might an engineer collect data?
- Why might an engineer work with others like you did today?
- You faced constraints today; how might an engineer face constraints?

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

Standard

3-PS2 Motion and Stability: Forces and Interactions

www.nextgenscience.org/pe/3-ps2-2-motion-and-stability-forces-and-interactions

- The chart below makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities.
- The materials, lessons, and activities outlined in the article are just one step toward reaching the performance expectation listed below.

Performance Expectation

3-PS2-2. Make observations and/or measurements of an object's motion to provide evidence that a pattern can be used to predict future motion.

DIMENSIONS	CLASSROOM CONNECTIONS
Science and Engineering Practice	
Planning and Carrying Out Investigations	Students make a plan for reaching the X and execute the investigation. Students will make adjustments to their launch to get closer to the X.
Disciplinary Core Idea	
PS2.A: Forces and Motion The patterns of an object's motion in various situations can be observed and measured; when that past motion exhibits a regular pattern, future motion can be predicted from it.	Students use their data to make predictions of marble travel.
Crosscutting Concept	
Patterns	Students make predictions on marble travel using various surfaces. Students discuss the patterns related to surface type and distance traveled.

- You had to be creative to get your marble close to the X, why might an engineer be creative?
- Why do you think engineers might have to try multiple times when designing their solutions?
- Why do you think engineers don't use a step-by-step process when they are working?

Conclusion

Although we don't believe engineering should take the place of science instruction, applying engineering practices and principles to science learning may improve student learning of disciplinary core ideas. Yet, doing engineering is not enough. Instead, we leverage the engineering tasks as a context to help our students understand how engineers work and why they work the ways that they do. ●

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