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Reconsidering Elements of Research and Practice

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NOTES FROM THE FIELD

Using the Sphero BOLT to Engage Students Mathematically

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ABSTRACT in this paper, we discuss the utilization of an innovative learning tool, the Sphero BOLT robot, in a 10-day algebra-based mathematics education course for graduate students. Students created routes for their BOLTs to travel and determined ways to measure the distance, rate, and time of their robots' movements. The student prompt, sample student work, class time considerations, and sample student-written reflections about the activity are detailed, in addition to implications and suggestions for teacher educators.

KEYWORDS *algebra, robots*

Introduction

The use of technology in a mathematics classroom is a vital component of learning (NCTM, 2000), and the available instructional technology changes drastically from year to year. Utilizing STEM-based lessons with a mobile application-controlled robot, such as the Sphero BOLT (Sphero, Inc. 2019), to teach mathematics concepts is also becoming more popular (Dunbar & Rich, 2020). Robotic activities have led to science, technology, engineering, and mathematics (STEM) learning engagement improvements (Kim et al., 2015). The use of robotics has been shown to have positive effects on students' spatial ability (Coxon, 2012) and their interpretation of graphs (Mitnik et al., 2009). According to Ioannou and Bratitsis (2016), "problem solving, literacy, creativity, and motivation are positively influenced when children access technology in their learning environments" (p. 3).

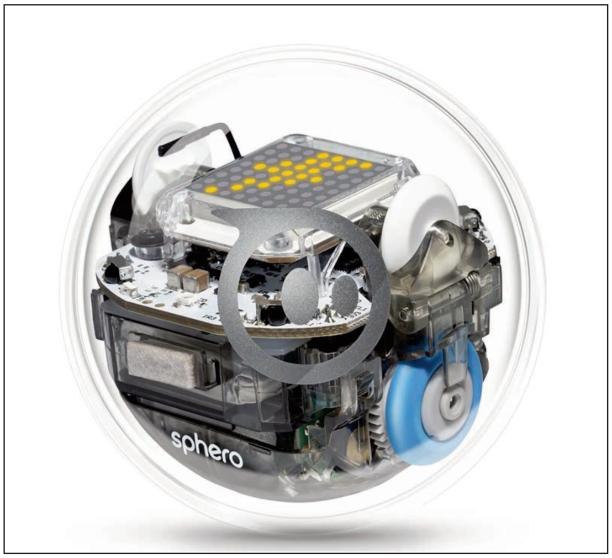
Robots are most commonly used with K-12 students during summer programs, after-school programs, elective courses, and robotic competitions (Altin & Pedaste, 2013; Barker et al., 2010; Larkins et al., 2013; Shepherd et al., 2019; Williams et al., 2007). In the classroom, the research on particular use of the Sphero BOLT is limited (Dunbar & Rich, 2020); however, the Sphero SPRK robot has been used in the kindergarten classroom for speed-related STEM activities (Ioannou & Bratitsis, 2016). Therefore, teacher educators should understand how such technology can be incorporated into their mathematics education courses so that they can prepare future and current teachers to use it in their classrooms. Additionally, there exists limited research on the use of robots in college mathematics classrooms. Therefore, the purpose of our work is to help fill this gap and show how the Sphero BOLT was utilized in a college mathematics education class.

Accordingly, we detail the use of pre-built BOLT robots in a graduate mathematics education class offered in the summer, which focused on teaching algebra topics covered in middle school to current and future mathematics educators. In this course, four graduate students, two pre-service and two in-service teachers completed two algebra-based projects using the Sphero BOLT. More specifically, in reference to mathematics standards, we detail the first classroom project (see lesson prompts in the Appendix) utilizing CCSS.MATH.CONTENT.6.EE.C.9: *Use variables to represent two quantities in a real-world problem that change in relationship to one another*. In particular, the graduate students were examining the relationships among distance, speed, and time. Students were required to keep one variable constant and look at the connections between the other two variables. Through this classroom episode, insight into how teacher educators and future teachers alike can utilize the BOLT in their respective classrooms are discussed.

About the Sphero Bolt

Figure 1 shows an image of the Sphero BOLT, a grapefruit-sized sphere with a durable transparent shell that has been recently introduced to the public.

Figure 1
The Sphero BOLT robot



The BOLT relies on wireless charging, so there are no wires or openings on the exterior, and the motors and display are balanced, protecting the internal electronics. The pre-built, self-contained structure of this robot allows for teachers to utilize it in a variety of lessons; for example, it can be used in drawing and tracing activities in which the BOLT can be covered in wet paint and then driven or programmed to follow specific paths. Such an activity enables students to explore the movement of the robot in relation to their commands. The BOLT can be used at different grade levels since users can interact with the robot in a variety of different ways. One such way is the use of a touch-based mobile application that controls the robot's movement through blocks of code that can be dragged and dropped.

The drag-and-drop interface provides a programming experience similar to such programs as Scratch (2020). This allows students to drag "code blocks," which signify logical structures, input controls, and output controls into different arrangements, then they can insert values for pre-built variables to programmatically control actions. Using these pre-made blocks of code helps students focus first on the mathematical concepts at hand and second on the coding aspect of the lesson. Additionally, while the robot features 360-degree motion, the remote-control application also allows users to explore the concepts associated with labeling 0 degrees as directly forward and 180 degrees is directly backward. A student could then drive the robot using the application by dragging their finger from a designated center point in different directions of motion. In the lesson we describe, graduate students were able to explore how the robot could be used to teach mathematical concepts using both features of this interface.

Class Specifics

The participants described in this classroom episode consisted of four graduate students enrolled in a 10-day summer mathematics education workshop at a university in the south-central United States. The students met for four hours each day for two weeks. The workshop for future and current teachers focused on middle school algebra-based mathematics standards. The use of technology in mathematics education was a central focus of the class. Therefore, the instructor demonstrated how to use graphing calculators, Vernier motion sensors (Bluetooth enabled sensors that measure distance/speed/time), algebra-based iPad-based applications, and Sphero BOLTs to teach algebra topics.

Before the work with robots, the students worked for approximately 60 minutes with Vernier's motion sensors, similar to Texas Instruments' calculator-based rangers (CBRs™), to develop a deeper understanding of movement in relation to distance/time graphs. The motion sensors were placed in front of students to measure student movement toward and away from the sensor. Graphs were produced on students' iPads and were discussed in detail.

To continue the discussion of distance/time/speed relationships, the instructor introduced students to the Sphero BOLT. The participants also had approximately 30 minutes of individual class time to familiarize themselves with the robot and its associated technology. The students could either use the application to move the robot with their finger and/or use blocks of code to move the robot along the floor. This exploration was open-ended; the instructor provided students with a great deal of freedom with respect to how to initiate movement of the BOLTs. This time was necessary for students to familiarize themselves with the technology as well as alleviate any anxiety associated with using a robot for the first time. The instructor circulated the room to answer any questions students might have about the application and robot. Students were able to use the Sphero Edu (Sphero Inc., 2019) application with ease and were able to move the robots once they were connected (Sample instructions on how to move the BOLT are provided under Step 2 in the sample lesson prompt at the end of the article.)

Lesson Details

Students then completed the BOLT-based project in groups of two over the span of 90 minutes. Group work and collaboration was encouraged throughout the activity. The instructor of the course has often utilized children's literature as a theme in her mathematics education classes to help future teachers see the value in using children's books to contextualize and teach mathematics (Jao & Hall, 2018). To demonstrate this and provide a context for the current lesson, the instructor utilized Kate Toms' (2009) book The Itsy-Bitsy Spider.

In the Sphero project, students listened as the instructor read parts of the story to provide context for the activity. Similar to the spider in the story who traveled out a waterspout and around town to get back home, the students were asked to create a story about a journey that the BOLT robot took. Although the students were free to produce paths of their choosing, they were required to incorporate at least three stops, as well as paths that were both straight and curved. These requirements were included to increase the cognitive demand of the activity.

Students created a path on sheets of poster paper and a corresponding storyline for their BOLT robot. They then utilized the Sphero block coding feature of the Sphero education application to generate blocks of code to move their robots along the path described in their storyline. The instructor pointed out to students that they only needed to repeat two specific lines of code, "roll __ degrees at __ speed for __ sec," and "STOP" to be successful in moving their BOLTS, but left open the opportunity for students to be more creative with these commands, such as including words and colors to their robot through different coding schemes.

Of the two required lines of code, the first corresponded to rolling their robot in a certain direction with a designated speed and time. The second line of code made their robot stop. Even though there were only two lines of unique code required, students had to determine which mathematical values to input in the code each time to move the robot correctly. Students could use various devices, such as tape measures to measure distance, their phones to measure time, and protractors to measure angles.

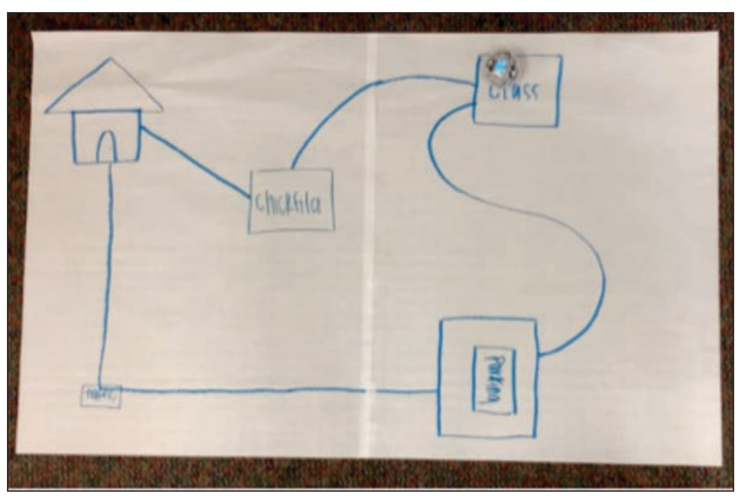
Sample Work

Both groups created paths that detailed their robot going through a series of straight and curved routes. As an example, Figure 2 shows the path designed by one group, wherein their BOLT robot left home, got caught in traffic, parked, went to class, traveled to a restaurant to eat, and then returned home.

All students initially struggled with determining the correct values for direction, time, and speed that would make their robot move down each of their predetermined paths. Students also needed practice using tools such as protractors and tape measures. Students often moved their robot off-course and adjusted their values for direction, distance, time, and speed. After some exploration, both groups of students successfully produced working code. Perhaps more important to their learning and future teaching, the student groups were able to wrestle with relationships among the coding structure and the distance, speed, and time of the robot.

Figure 2

Sphero BOLT on sample student route



Note: This sample of student work was selected since they included some of the optional features, such as changing the color of their BOLT and writing phrases on their BOLT when at various stops.

Creating correct direction headings for the BOLT was difficult for some students. For example, a heading of 0 degrees (with the blue BOLT alignment light facing the person) would move the BOLT forward, and a heading of 180 degrees would move the BOLT backward. Students were more familiar with relying on traditional x- and y-coordinates for direction. However, the remote-control application for the BOLT robot requires direction headings to be in terms of angle measures and mimics how a person perceives their orientation in space.

For fun, the group that created the paths in Figure 2 also added color (e.g., red) to their robot and phrases (e.g., the word WAITING) that would scroll across the LED screen of the robot to simulate when their robot was waiting in traffic. Figure 3 shows a code created by the students.

Student Reactions

In a written reflection about the activity, all students commented on how they enjoyed working with the BOLTs. More importantly, students also commented on how this activity could help their future students learn mathematical concepts such as distance/time relationships within a relatable common context. One student, who was uncomfortable with technology in general, commented:

> I am severely allergic to technology, so I was uncomfortable at first. I warmed up a bit during the first activity (playing around with BOLT).…Students could benefit from Sphero Activities…To see a 1D graph on paper vs. seeing a graph that they constructed through an activity that they created will solidify concepts and aid them in making connections to real-world activities. Really cool stuff. Thanks for stretching me today and getting me out of my comfort zone.

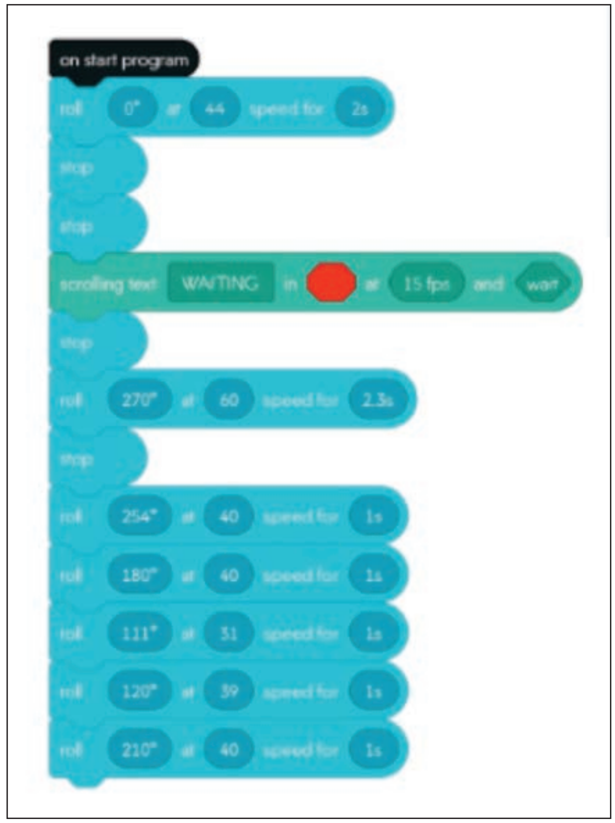
Another student commented on the usefulness that she sees in BOLT in the mathematics classroom:

> I loved today's activities!! The problem-solving skills required would be great to workout anyone's brain! I had fun working with the BOLTs while also using angles and speed variables to learn. I think this would be a good introduction to distance and velocity.

In a future lesson of this type, it would be meaningful to expand upon this students' comment and demonstrate how this activity could be used as an introduction to speed, time, distance, and velocity. Also, in the current lesson, the students engaged in making hypotheses and then testing them; however, in the future it would be useful to model for the current and future teachers how to help their students formalize such conjectures.

Figure 3

Sample student code



Conclusion

Even though students initially struggled with creating correct distance, speed, and heading values to make their BOLTs move, they were ultimately successful. This productive struggle on the part of the pre-service teachers provides a context for them to use this meaningfully in their future classrooms. If given to an appropriate set of students with the correct support, the pre-service teachers could engender the same struggle and learning they experienced in this activity. Additionally, since only two unique lines of code are required to move the robot successfully, the aspect of this assignment that requires coding is rudimentary enough, and foreign enough to provide students who are new to coding an exposure to such concepts. Therefore, access to the mathematical and computer scientific concepts of such a lesson permit student engagement at a wide range of educational levels.

An important part of this lesson was the open-exploration time given at the beginning for students to familiarize themselves with the BOLT. This allowed them to explore intuitive notions of the robot's movement in comparison to the coding structure. However, in future lessons of this type, the instructors may include guided explorations, such as providing guidance for basic, horizontal, or vertical paths before having them move on to more complicated ones. The instructors should consider further the space in which this activity is taking place since it was easy for the BOLTs to collide with other objects or fall off tables. Another consideration for a future lesson may be the inclusion of a worksheet where students could document their trials and errors and provide explanations for their successes and failures. This could help students regulate their progress as well as have a valuable record of what mathematical learning was taking place. Lastly, prior to the lesson, a review of using appropriate tools such as protractors and tape measures may help all students focus on new mathematical concepts instead of recalling prerequisite ones.

An important aspect of the lesson that is particularly meaningful for future teachers is the modeling by the instructor of best practices for developing conceptual understanding. The instructors demonstrated how to generate and maintain discourse with students to help develop mathematical understanding, particularly with respect to the relationships of distance, rate, and time. The instructors modeled how to circulate the classroom during the activity and ask probing questions. Additionally, the instructors modeled how to ensure the activity was student-centered and student-driven by providing structure and guidance when needed, but also providing independence when needed as well.

This activity may interest mathematics teacher educators since it explores the use of an innovative technology in the teaching of mathematics. Although the students in the course were familiar with concepts related to distance, rate, and time, they were unfamiliar with how the technology introduced could be utilized to teach these concepts. As a result, students could authentically use these new experiences to provide engaging activities for their future mathematics students. Additionally, pre-service teachers benefit from engaging in innovative problem-solving activities where best practices are modeled by seasoned instructors. Activities such as the one discussed in this paper also provide evidence that an interdisciplinary approach is possible in certain settings. The current lesson provides future teachers with an example of how to combine innovative technology; mathematical and computer scientific conceptual learning; and even literature into one lesson.

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Appendix

Activity

Step 1: Using the Itsy Bitsy Spider's adventure theme, create your own storyline and journey for a character of your choosing. Your character must travel to at least three places, with at least one path being curved and one being horizontal. Sketch your maze in the space provided. Once finalized, draw your path on the poster board and label each stop. (Remember, you must have at least 3 stops with at least one curve path and at least one horizontal path.)

Step 2: Now, using your Sphero BOLT and the Sphero Edu app, create code to move your BOLT through your maze.

Directions for using the Sphero app: Tap on the Sphero Edu icon. Go to My Programs, the plus icon, and choose Blocks code program type and the Sphero BOLT robot. Click Create. You can now drag and drop code onto your screen. (NOTE: The only two lines of code needed are to repeat two specific lines of code, "roll __ degrees at __ speed for __ sec," and "STOP" to be successful in moving BOLT, but you can get creative with your code by adding words and colors to your robot through different coding schemes.) When you are ready to test run BOLT, press START. The program will look for your BOLT to connect (make sure Bluetooth is on) and then run through your code. Have fun!!

In the space provided, list your lines of code and values. By each line of code, explain why you chose the specific degrees, speed, and seconds you selected.