How Fast Is the TI-Rover? Introducing Middle School Students to Slope and Linear Equations

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Abstract: *The author engaged 6th-grade completers in a fun activity involving Texas-Instruments Rovers, CBR 2 motion sensors, and TI-nspire graphing calculators, introducing them to the linear equation slope via the statistical problem-solving process. In this paper, the author discusses students' engagement, warts and all.*

Keywords: *multiple representations, problem solving, slope, graphing technology*

1 Introduction

The Common Core State Standards for Mathematics (CCSSI, 2010) emphasize the slope of the linear equation in the 7th grade. Students must be able to "graph proportional relationships and understand the unit rate informally as a measure of the steepness of the related line, called the slope" (CCSSI, 2010, p. 46). We hoped to achieve this goal with 6th-grade completers who attended a STEAM summer camp at a southern university campus by engaging them in the TI-Rover activity. During this activity, the students had to find the speed of the TI-Rover using the CBR 2 motion sensor. Figure 1 shows a picture of students' engagement using the CBR 2 to collect data to find the speed of the TI-Rover.

Figure 1: *Students using CBR 2 to find the TI-Rover speed.*

2 How Fast is the Rover? Introduction

Through this instructional activity, we wanted to introduce the students to linear equations and their slopes by finding the speed of the TI-Rover using the CBR 2 and the TI-*n*spire CX II calculator. The calculator displays a graph that represents the relation between the time (i.e., the independent variable) and the distance (i.e., the dependent variable) [as shown in Figure 3]. The students are supposed to be familiar with

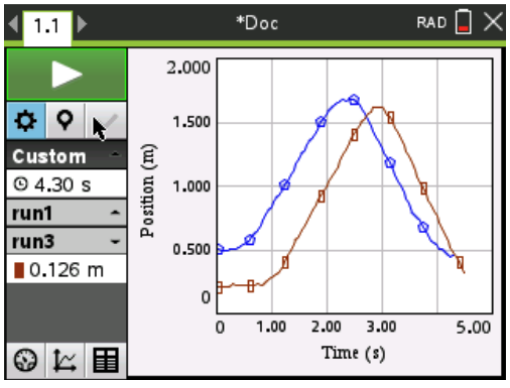
- Apply knowledge of arithmetic to read, write, and evaluate algebraic expressions.
- Use equations and inequalities to represent and solve real-world or mathematical problems.
- Identify and analyze relationships between independent and dependent variables. (Alabama State Department of Education, 2019, p. 60).

We started by engaging the students in a small exercise to familiarize them with how the CBR 2 collects and sorts data. We connected the CBR 2 to the TI graphing calculator. One of the camp's preservice teachers carried the CBR 2 and recorded the data using the graphing calculator for a student who walked forward and backward in front of the CBR 2. We used the TI navigator system to mirror the graphing calculator's screen on a large screen in the classroom (see Figure 2).

Figure 2: *Using CBR 2 to collect data.*

After recording data from the first student's motion, we asked the students one by one to come and move in front of the CBR 2 to match the first chart. Students were encouraged to receive advice from their classmates on how to move to match the original curve, such as where to start, when to go fast, and when to slow down. Figure 3 shows how the data were represented after another student tried to match the initial curve (i.e., blue). Ten students in the class worked in groups of three or four.

Figure 3: *Trying to match the initial curve.*



After completing the previous small group activity, we engaged the students in a class discussion about what they noticed about the relationships between the position, the time, and their units. To conclude this opening activity, we posed the following question: If we would like to drive to a city 70 miles away from the present location and get there in one hour, how fast should we go, assuming there are no stops or slowdowns? Students agreed that the speed should be 70 miles/hour. However, some students were confused by the unit "meter" (m) in Figure 3. The reason for the confusion is the TI-*n*spire graphing calculator displays the readings from CBR2 in meters per second, as shown in Figure 3. We showed them a one-meter-long ruler with a metric scale to demonstrate what one meter looks like.

3 How Fast is the Rover? The Primary Activity

The primary activity was composed of three parts: (1) Data collection, (2) Data analysis, and (3) Result interpretation (American Statistical Association [ASA], 2020). The activity started with the students receiving a handout, which is included in the appendices. It was adapted from the Texas Instruments website. Major changes were made to it to meet the goals of the activity. The handout provided stepping-stone procedures for collecting and analyzing data before interpreting the results.

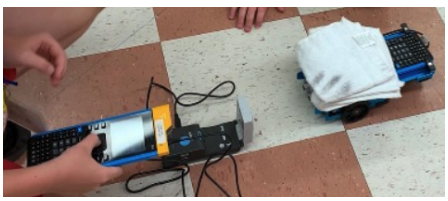
3.1 Data collection

The students had to place the T-Rover 50 cm away from the CBR 2 and program it to drive another 50 cm away from the rover while collecting data. The students had been shown how to program the TI-Rover to drive it the day before. The appendices include detailed steps on how to use Python to program the TI-Rover. Figure 4 shows the students engaged in collecting data to find the speed of the TI-Rover.

Figure 4: *Collecting data to determine the speed of the TI-Rover.*

One of the major issues that the students faced was collecting valid data because the CBR 2 can pick up interference from other objects. We emphasized that the students must ensure a clear path between the TI-Rover and the CBR 2. Group 1 decided to enlarge the size of the TI-Rover by placing small towels on its top to collect more valid data, as shown in Figure 5.

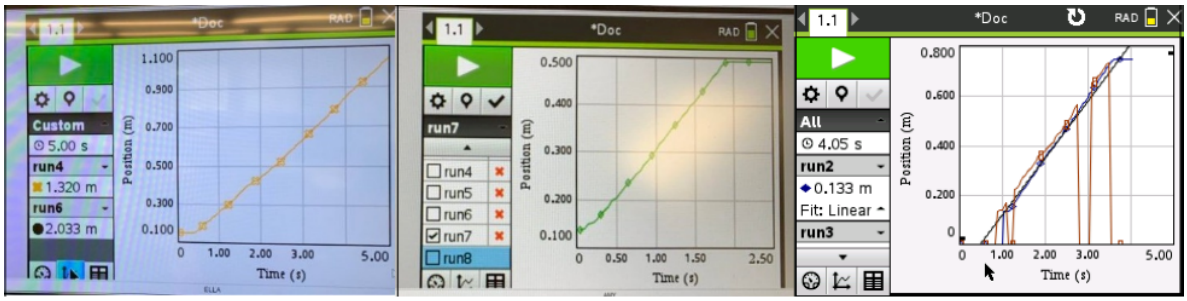
Figure 5: *Enlarging the size of the TI-Rover to collect more valid data.*



3.2 Data analysis

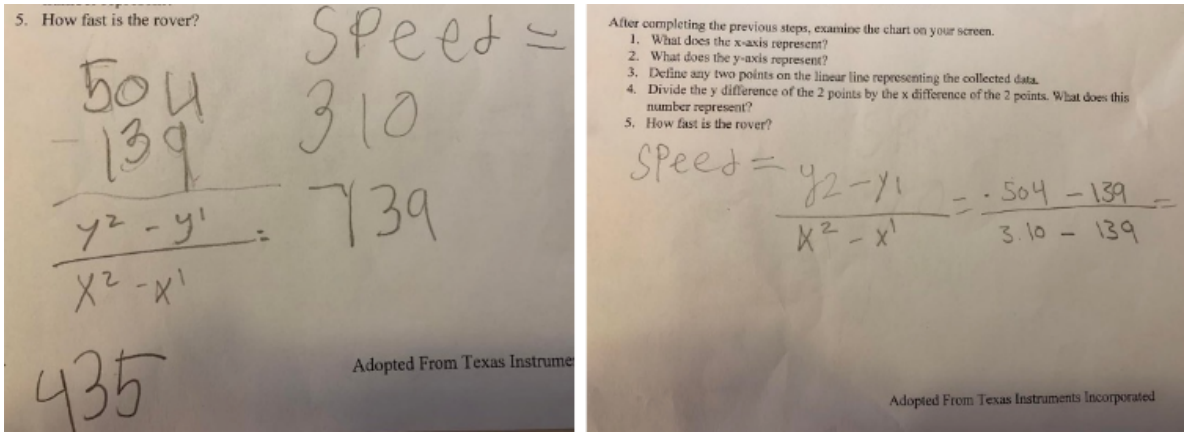
After several attempts, all groups could collect valid data, as shown in Figure 6. The CBR 2 generates these charts automatically after collecting the data. We noticed Groups 1 and 3 programmed the TI-Rover to drive more than 50 cm.

Figure 6: *Representing the data using charts.*



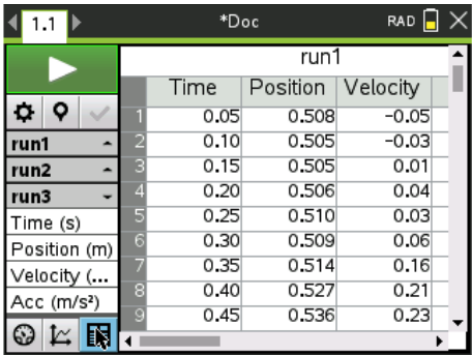
At this point, 15 min remained in the activity. All groups struggled to define two points on the linear equation created on their calculators (i.e., Steps 3 and 4 of Part 2). Only one group attempted and miscalculated the slope, as shown in Figure 7.

Figure 7: *Miscalculating the slope of the linear equation.*



We noticed an issue with writing the correct mathematical expressions by examining the student work samples. For example, the students used X^2 and Y^2 instead of X_2 and Y_2. In addition, we noticed that the students used numbers that were difficult to define using the charts. The students used the data table that the CBR 2 generates on a different tab on the TI graphing calculator (see Figure 8).

Figure 8: *Generating data table.*



Using (x, y) coordinates from the data table is practical. However, teachers may predict and be ready to address the following misconceptions. First, valid data occur after the 1 st sec, as shown in Figure 5. The CBR 2 needed 1 sec to detect the TI-Rover. Second, the students may struggle with decimals. For example, the students decided to remove the decimals from the numbers.

Considering the short time that remained in the activity, we suggested that the students find the best regression line that fits the linear equation in their charts using the graphing calculator (Figure 9). Then, the students could define linear regression equations that represented their data charts, as shown in Figure 10.

Figure 9: *Steps of finding regressions for the data charts.*

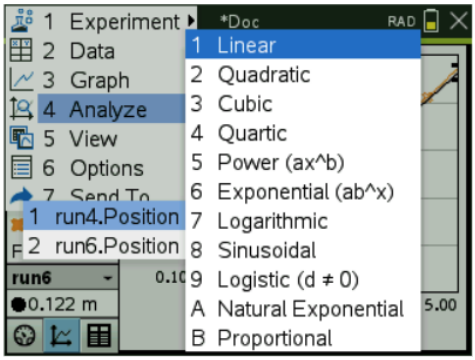
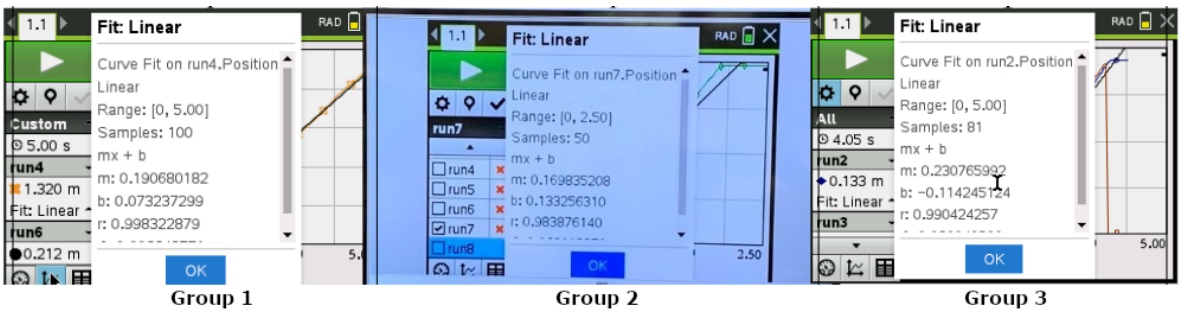


Figure 10: *Finding regression equations for the data charts.*



3.3 Result Interpretation

We met with each group separately to discuss their regressions as they finished. During our discussions, we aimed to introduce the students to the range, sample, linear equation ($y = mx + b$), and slope (m). After the discussions, the three groups decided the speed of the TI-Rover was 0.19, 0.17, and 0.23 meters/sec, respectively. As we noticed the differences, we showed their calculators on the class screen and asked why we had such differences. Group 3 mentioned that they programmed the rover to drive faster, which was an option and creative decision by the students of this group. Group 1 said that they collected data for a longer distance and time, along with enlarging the size of their rover, which might make their number more accurate (Figure 6). The students realized that having a larger sample might provide better results.

4 Final Thoughts

4.1 Finding the slope

Students struggled to find the slope (Steps 3 and 4, Part 2 of the handout), as they were unfamiliar with the process. To deal with this matter, we could have discussed the slope and how to find it during the opening activity by defining two points and asking them to find the rate of change. We might have asked about the rate of change for a linear proportion from the blue curve shown in Figure 3 and connected it to the speed and the slope. In addition, we could have presented the students with a linear equation and asked them to match the line instead of a curve created by their movement in front of CBR 2 (Remijan, 2019).

4.2 Data table

As shown in the data table (Figure 8), the velocity is presented in a column. Since the velocity data are there, they should be discussed and addressed. However, if it is preferred not to handle such data at this point, the setting can be adjusted to hide the velocity column.

4.3 Time

It is evident that 1.5 hours was not enough time to enact the activity as planned, especially toward the end. When we led group discussions about the linear equation and its slope, it was more of a teacher-centered approach, which may have reduced the cognitive demand of the activity (Stein, Smith, Henningsen, & Silver, 2009). We believe the activity needs at least 2 hours to be enacted effectively. To help enact this activity, we present Table 1, which suggests how the activity can be adopted for different class time lengths. Eventually, it is up to the teacher to adapt and adjust the activity as needed.

4.4 Equity

Not every classroom can access these TI tools to enact this activity. However, Texas Instruments has a loan program to ship this equipment back and forth for free. You may use this link to learn more about the loan program: https://education.ti.com/en/customer-support/workshop-loan-program.

Table 1: *Adjustment of the activity (i.e., planned curriculum based on different amounts of time).*

Time	Planned Curriculum of the Activity
3 hours (i.e., three class periods)	The activity can be enacted as it is presented with a few changes, as suggested in the previous two paragraphs, assuming the students are unfamiliar with TI-Rover programming to drive it. The first hour will introduce the students to the TI-Rover programming language and let the students explore the rover (A handout is provided to help with programming the TI-Rover). At the end of the activity, the students may explain their work to the rest of the class.
2 hours (i.e., two class periods)	The activity can be enacted as it is presented with a few changes, as suggested in the previous two paragraphs, assuming the students are already familiar with TI-Rover programming to drive it. At the end of the activity, the students may explain their work to the rest of the class.
1 hour or less (i.e., one class period)	The teacher may demonstrate programming the TI-Rover to drive in front of the CBR 2 and collect the data, then display the graph for the class and ask them to work in groups to investigate the chart and define the rover's speed. Also, the teacher may ask a student to demonstrate moving in front of CBR 2 and investigate the student's speed instead of the TI-Rover.

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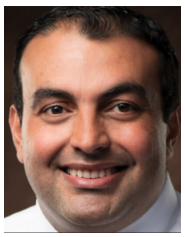

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APPENDIX A: *How Fast is the Rover?* Student Handout

How Fast is the Rover? The Slope of the Linear Line

Adapted From Texas Instruments Incorporated

Speed and velocity are concepts that you have observed since early childhood. Because velocity is the derivative of displacement, a closer look at position and velocity can develop a deeper understanding of how derivatives and their functions are related.

In this activity, you will use a Calculator-Based Ranger™ (CBR™) data collection device with your graphing handheld to collect motion data with specific characteristics and use that data to conclude the relationship between position and velocity. Our goal is to find the speed of the TI-Rover.

Part 1: Data Collection

1. Place the CBR™ at least 50 cm away from the rover.
2. Make sure no objects are between them.
3. Program the rover to drive away from the rover then. The rover should not go more than 100 cm away from the rover.
4. As soon as the rover starts driving away from the CBR™, press the green button on your handheld screen connected to the CBR™ to record the data.
5. When the rover stops, press the red button on your handheld screen, which is connected to the CBR™.
6. Save the data on your screen represented in a chart.

Part 2: Data analysis

1. What does the x-axis represent?
2. What does the y-axis represent?
3. Define any two points on the linear line representing the collected data.
4. Divide the y difference of the 2 points by the x difference of the 2 points. What does this number represent?

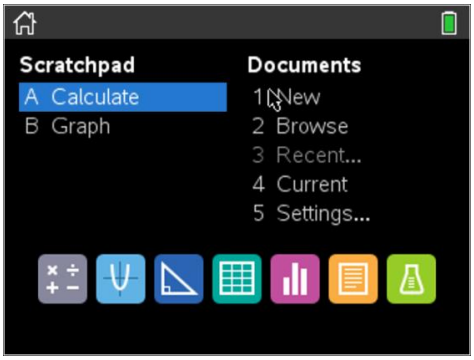
Part 3:

1. How fast is the TI-Rover? Justify your answer.

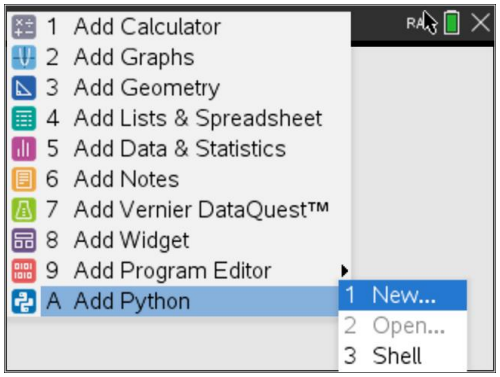
APPENDIX B: The Steps of Programming a TI-Rover

The Steps of Programing the TI-Rover Using Python Language

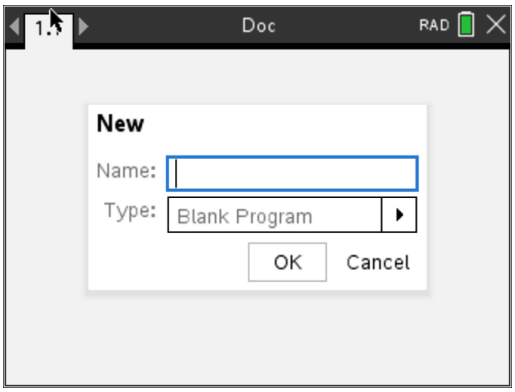
Step 1: From the home page, select “NEW”



Step 2: You will get a new page with ten options, Select “Add Python” and then “NEW”

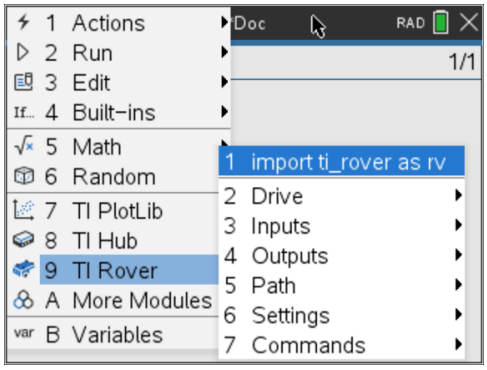


Step 3: Name your program, no space, then press “OK”

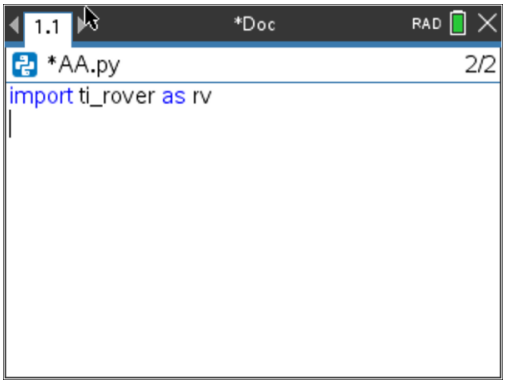


Step 4: You should get a Python page in which you write your program

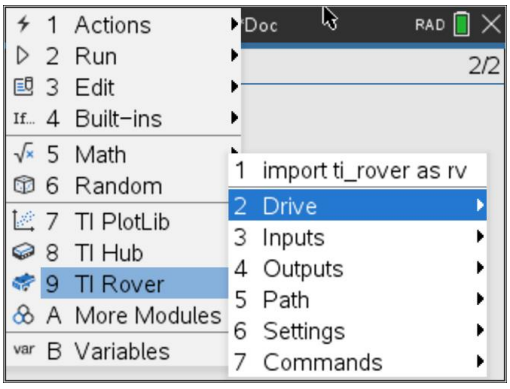
Step 5: Press “Menu,” go to Option 9 (TI Rover), then select Option 1 (import…)



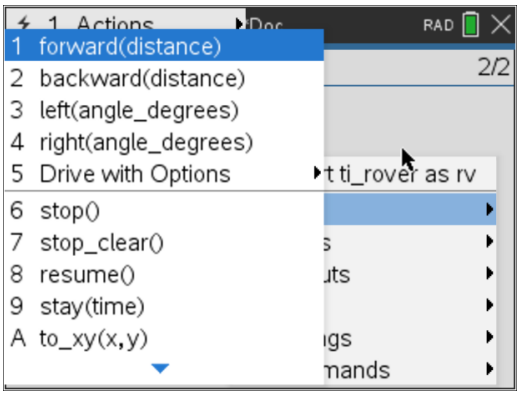
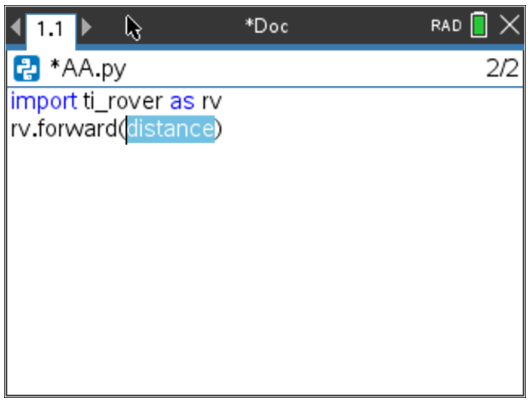
Step 6: TI rover has been imported to your Python language; the rover is recognized as “rv”



Step 7: Now you are ready to drive the rover, go to “Menu,” “TI Rover,” then “Drive”



Step 8: You will get several options one of them is "forward (distance)"



Step 9: Make sure to define the distance that you would like to go.