The Eurasia Proceedings of Educational & Social Sciences (EPESS)
ISSN: 2587-1730

The Eurasia Proceedings of Educational & Social Sciences (EPESS), 2016

Volume 5, Pages 273-278

ICRES 2016: International Conference on Research in Education and Science

EXPLORING GRAPHING THROUGH PROGRAMMABLE ROBOTS

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Abstract: Eight sixth-grade students in a gifted learning center in an urban city in the central part of Turkey explored graphing using programmable robots. The purpose of this study was to describe how these students engaged in this activity and utilized robots to test their conjectures that they developed for the interpretation of given distance/time and position/time graphs. Data were primarily gathered through classroom observations, document analysis and interviews. The results showed that initially students had difficulties interpreting both distance/time and position/time graphs and writing appropriate scenarios for the given graphs. Specifically, students initially interpreted those graphs as velocity/time graphs and wrote scenarios accordingly. Furthermore, students had difficulties identifying the velocities for the given intervals on the graphs as well as interpreting the meaning of slope in relation to physical movement. Programming robots and testing their own conjectures with robots provided students with real-life experiences to make sense of graphing motion in relation to distance/time and position/time graphs. After programming the robots, students were able to see the graphical representation of their prediction and check whether or not their conjecture was consistent with the actual graph. As well, the students were able to articulate the physical meaning of slope and how it specifically relates to movement. The results showed increased student understanding regarding the relationship between velocity and distance on position/time graphs with the use of robots. Furthermore, the data also suggested that the students enjoyed using robots for exploring mathematical and science concepts and considered the use of the robots as beneficial to their mathematical understanding of distance/time and position/time graphs.

Keywords: Programmable robots, technology integration, graphing

Introduction

Educational robotics (ERs) are becoming popular in teaching and learning in content areas such as science, technology, engineering and mathematics (STEM) education. This type of technology provides learners a variety of experiences and meaningful learning opportunities (Mitnik, Nussbaum & Soto, 2008). Through using robots, students can construct and test many mathematical ideas and develop a stronger understanding of STEM content within a meaningful context. “When designing, constructing, programming and documenting autonomous robots, students not only learn how technology works, but they also apply the skills and content knowledge learned in school in a meaningful and exciting way” (Eguchi, 2014, p. 30). ERs can also be used to foster students’ graphing abilities (Alimisis & Boulougaris, 2014).

Proficiency in graphing is considered as an essential skill for understanding and learning in variety of content areas, including mathematics (Moreno-Armella, 2008), physics (Alimisis & Boulougaris, 2014; Beichner, 1994), and chemistry (Dori & Sasson, 2008). However, representing relationships between variables through graphing is a challenging task for many middle school, high school and even college level students. Research (Alimisis & Boulougaris, 2014; McDermott, Rosenquist, & van Zee, 1987; Woolnough, 2000) revealed some difficulties regardings students’ ability to graph, including “connecting graphs to physical concepts” and “connecting graphs

- Selection and peer-review under responsibility of the Organizing Committee of the conference

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to the real world" (McDermott, Rosenquist, & van Zee, 1987; p. 503). According to Roth and McGinn (1997), understanding graphs is a skill which can be learned through practice and experience in different modalities. Therefore, providing fruitful learning environments with various experiences in graphing is crucial for students to develop an understanding about graphs. ERs can support such environments because students find opportunities to make connections between graphs and motion in a meaningful way.

In this study, we explored how programmable ERs supported sixth grade students' development of distance/time and position/time graphs. We first interviewed eight sixth-grade students to reveal their initial understanding of distance/time and position/time graphs. Then, the students explored those graphs using robots. Our research question was, how do students initially interpret distance/time and position/time graphs and how do robots support students' changes in thinking of distance/time and position/time graphs?

Methods

Setting and Participants

Eight sixth grade students in a gifted learning center participated in the study. The students attended the center designed for gifted students two days a week for eight hours. These students were bussed to the center from various public and private middle schools throughout the city in the central part of Turkey. Students took enrichment courses designed for gifted learners in content areas like mathematics, science, social science, and robotics. All students already experienced how to program robots in previous lessons. Furthermore, all students had already taken a science course that included graphs before the study. The data for this study were gathered in the mathematics class.

Course Structure

A three-week course was designed to focus on graphing motion using programmable robots. Students met once a week for forty minutes per session. Participants explored all graphs using robots with an emphasis on distance/time and position/time graphs. Table 1 provides a structure to the activities and descriptions of the lesson explorations.

Table 1. Structure of the study

Week	Content	Description
One	Pre-interviews Distance/time	Pre-interviews were conducted with each participant. A sample distance/time graph was shown to the students and they were asked to interpret the graph and make conjectures about the possible motion of a robot that produces the graph. Lastly, students were asked to test their conjectures through programming robots and see whether or not their predictions were correct.
Two	Position/time	A sample position/time graph was shown to the students and they were asked to interpret the graph and describe relationships between the graphs and the velocity. Students were asked to test their conjectures through programming ERs and see whether or not their predictions were correct.
Three	Review of graphs Post-interviews	Students were asked to interpret the given distance/time graphs and position/time graphs. Post-interviews were conducted with each participant.

Data Collection

Data were primarily gathered through classroom observations, document analysis and interviews. In order to explore the changes in thinking and understanding in relationship to distance/time and position/time graphs, pre- and post-interviews were conducted with each participant at the beginning and at the end of the study. Additionally, the participants were observed throughout the classroom sessions. Classroom observation notes were taken and later transcribed for data analysis purposes. Students' drawings were also collected for data analysis purpose.

Data Analysis

Initially, all students' understandings of distance/time and position/time graphs are examined. Later, students' growth in understanding and changes in thinking of these graphs using ERs was analyzed. Specifically, the researchers tried to understand how students' thinking changed when they observed the movement of robots. In the post-interviews, students were asked to interpret two given graphs (a distance/time graph and a position/time graph) and write a scenario for each of the graphs. Additionally, two scenarios were provided and students were asked to draw graphs accordingly. The purpose of the post-interviews was to understand students' growth in understanding these graphs after the use of ERs.

Results and Findings

Initially, most of the participants had a limited understanding of both kinds of graphs (distance/time and position/time graphs) based on the pre-interviews.

Initial Understandings: Distance/Time Graph

Initially the majority of students interpreted distance/time graphs as velocity/time graphs. A sample student response is provided below (Figure 1):

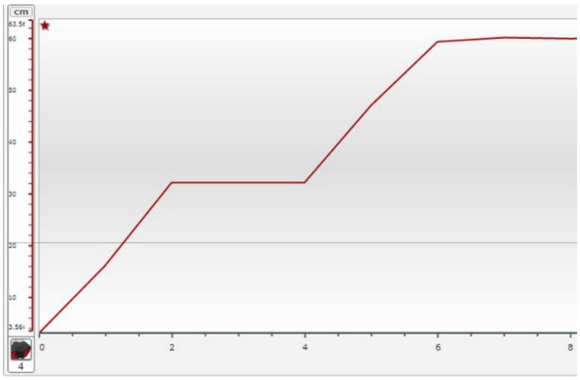


Figure 1. Distance/time graph

R: What can you tell me about the graph?
S-1: An ant is accelerating. Then it stops. Then it is accelerating again.
R: How do you know it is accelerating?
S-1: The line goes up (pointing to the line).
S-2: No, look at it, it is a distance/time graph, not a velocity/time graph.
R: What can you tell me about the velocity then?
S-2: It is constant.
R: How do you know that?
S-2: I checked the distances in the first and second time period. It is the same.

Initial Understandings: Position/Time Graph

Position/time graphs were also interpreted as velocity/time graphs by some of the students. A sample student response is provided below (Figure 2):

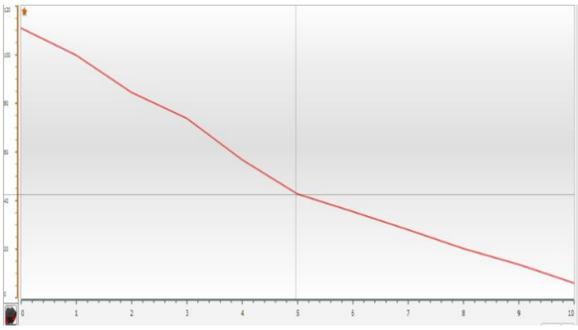


Figure 2. Position/time graph

R: What can you tell me about the graph?
S-3: It is decelerating.
R: How do you know it is decelerating?
S-3: The line goes down (pointing to the line).
R: What can you tell me about it?
S-4: In five seconds, the vehicle goes 70 cm further away. Then in the next five seconds it goes 40 cm away.

S-4 did not recognize that the vehicle was getting closer instead of moving away. He also focused on the distances in centimeters instead of the position of the vehicle.

Using Robots to Explore Distance/Time Graphs

After the initial interviews, students were asked to write scenarios for each graph (Figure 1 and Figure 2) and then program the ERs to test their initial speculation on how to create the graph. With a few trials, students who used the ERs realized that they could not get the graph shown in Figure 1 with an accelerated speed. Then, they tried a constant speed to see how the new graph was generated. Students quickly realized that the velocity should be constant when they observed the graph that was generated by the computer based on the ERs movement. However, finding the speed seemed to be a challenging task for the students. A few students focused on the distances in the 0-2 and 4-6 second time intervals. They found that in the 0-2 second time interval, the speed was 30/2=15 centimeters per second. It was the same challenge for the 4-6 second time interval as well (see Figure 3). Although they found that the speed was the distance travelled per unit time, it was difficult for students to translate that knowledge into programming since power is used instead of speed when programming the robot. Initially, some students used trial and error strategies to construct a similar graph using the robots:

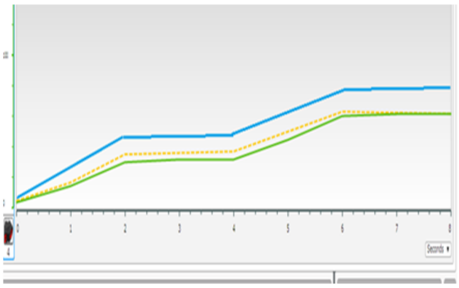


Figure 3. Students' exploration of distance/time graph

S-5: Let's try the speed [power] at 40. Go with the speed of 40; then stop; then go with the speed of 40 again.
R: The graph (1st trial) does not match with the given graph.
S-6: There is something wrong with our speed.
R: What can you do about it?
S-5: We should increase or decrease the speed. Let's decrease it.
R: Why is that?
S-6: If the speed is low, then the distance you go would be low. So we would get the graph.

Using Robots to Explore Position/Time Graphs

Students initially had difficulties interpreting negative slopes. First, they only focused on distance, but then they realized that the negative slope was about the direction and not about distance.

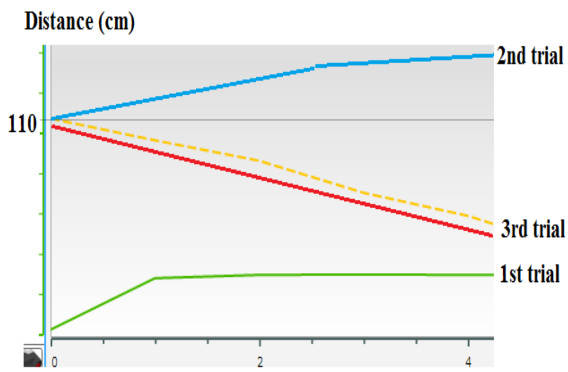


Figure 4. Students' exploration of position/time graph

S-4: It is supposed to be like the yellow line (1st trial) (see Figure 4).
R: Why did it is happened so? What do you think?
S-5: I don't know.
S-4: The distance should be 110 cm away from us! Not 0!
S-5: Let's try again.
R: Did it work?
S-5: No it did not.
R: Why do you think it did not work?
S-4: Because the vehicle is approaching us from 110 cm distance. It should work now!

Post-interview data: Distance/time graph

At the conclusion of the ERs lessons, students were asked to interpret the following distance/time graph (see Figure 5). Students quickly realized that the vehicle had constant but different speeds in the 0-2 and the 4-5 second time intervals.

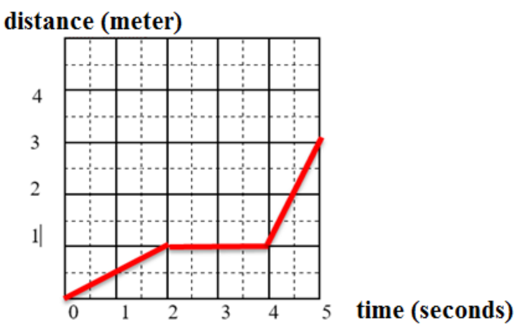
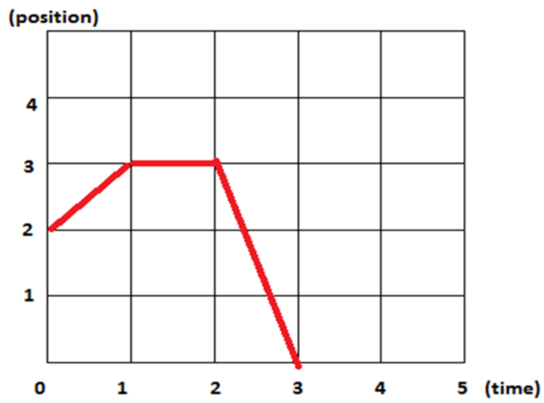


Figure 5. Interpreting distance/time graph

R: How do you know the speeds would be different in those time intervals?
S-5: Because of the distances the vehicle traveled. In the first interval (0-2) the vehicle traveled one meter. So the speed is .5. In the second interval (4-5), it travels 2 meters. The speed is 2.
R: How about the time interval 2-4?
S-5: The speed is zero. Because the vehicle does not move!

Post-interview data: Position/time graph

The students were also asked to write a scenario for the following position/time graph (see Figure 6). A sample student response is provided below:



S: A little boy who is 2 meters away from his home traveled 1 meter further away for one hour. He got tired and rested for another hour. Then he realized that the weather began to get dark and he ran back to his home in one hour.

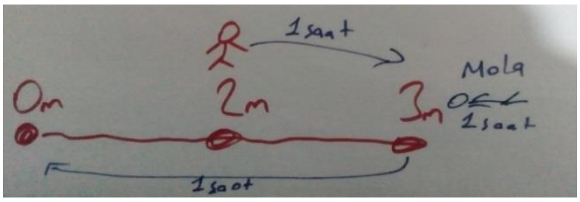


Figure 6. Interpreting position/time graph

Although the student could not write a realistic problem (traveling 1 meter in an hour), his general interpretation of the motion can be considered reasonable.

Conclusion

The findings of the study indicated that initially students had difficulties interpreting both distance/time and position/time graphs and writing appropriate scenarios for given graphs. Specifically, students initially interpreted given graphs as velocity/time graphs and wrote scenarios accordingly. Furthermore, students had difficulties identifying the velocities for the given intervals on the graphs as well as interpreting the meaning of slope in relation to physical movement. Programming robots and testing their own conjectures with robots provided students with real-life experiences to make sense of graphing motion in relation to distance/time and position/time graphs. After programming the robots, students were able to see the graphical representation of their predictions and check whether or not their conjectures were consistent with the actual graph produced by the ERs movement. As well, the students were able to articulate the physical meaning of slope and how it specifically relates to movement. The results showed increased student understanding regarding the relationship between velocity and distance on position/time and distance/time graphs with the use of ERs. Furthermore, the data also suggested that the students enjoyed using robots for exploring mathematical and science concepts and considered the use of the robots as beneficial to their mathematical understanding of distance/time and position/time graphs.

Our study showed improved learning growth when using ERs at the middle school level in relation to graphing. The technology helped students better articulate how the ERs movement connected to mathematical reasoning. Using ERs has been shown in several studies to improve student reasoning and thinking (Mitnik et al. 2008; Norton, McRobbie, & Ginns, 2007)). Mitnik, Recabarren, Nussbaum, and Soto (2009) conducted a study exploring the use of robots to investigate graph interpreting skills. They found that using robots was more effective in supporting graph interpretation than not using them; as well students appeared to be more motivated when using the robots. Mauch (2001) also found that using robots in the classroom is highly motivating to students.

Recommendations

The results of this study suggest that robots can be used to explore graphs and has the potential to enhance students' graphing abilities. While the study did not indicate complete understanding of graphs after using ERs (the students still used improper units (traveling meters in hours) to describe movement as see in Figure 6, students did gain insight and showed positive changes in thinking in regards to graphing. It is important to note that while three weeks did show measured, improved changes in thinking, students still needed more time. More emphasis on the meaning of units (seconds, centimeters/meters and corresponding speeds) is recommended as well as additional time to explore robots. Initially, the students focused on movement using the ERs; we recommend additional explorations focusing specifically on the meaning of units in relation to the ERs movement. Perhaps students could create corresponding distance/time, position/time and velocity/time graphs that all parallel and link to one programmed path of the ER. This study was conducted with gifted students. Further studies can be conducted to with students with variety of backgrounds.

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