Making Mathematical Meaning through Robot Enactment of Mathematical Constructs

Scot Sutherland, Tobin White, Jason Huang and Harry Cheng
University of California, Davis, One Shields Avenue, Davis, CA 95616
ssutherland@ucdavis.edu, twhite@ucdavis.edu, jvhuang@ucdavis.edu, hhcheng@ucdavis.edu

Abstract: Learners of algebra struggle to understand the meaning of the symbolic and graphical representations they encounter. This paper explores the possibility of using robot enactment of mathematical constructs as a surrogate to support mathematical meaning making. We describe the Number Line activity design in a classroom network of handheld devices informed by the results of a pilot study indicating that students connected mathematical values to robot position and the sign of a value to robot motion.

Mathematical Meaning and Physical Enactment

Making the transition from arithmetic to algebra presents learners with complex cognitive challenges (Herscovics & Linchevski, 1994). The same mathematical construct can have many different meanings and representations that must be connected and coordinated. Studies have explored the use of computer simulations and collaborative network technology to support learning necessary for algebra success (Hegedus & Roschelle, 2013). Nemirovsky, Tierney & Wright (1998) explored graphing supported by enacted physical phenomena.

The paper presents an initial exploration of robot motion as a surrogate (Fadjo, Hallman Jr, Harris, & Black, 2009) to enact and model mathematical objects through positioning and movement in relation to a Cartesian coordinate plane or number line. We present the results of an initial pilot study in which students input values into a command line interface on a laptop computer to move a group of robots to points on a coordinate plane that define the graph of a quadratic function. We describe how these results inform the design of the Number Line collaborative learning activity environment developed for a classroom network of iPod Touch handheld devices connected to a robot server. The preliminary results of this ongoing study are reported in the proposed poster.

Pilot Study Methods

The pilot study took place in two diverse K-8 schools, involving 132 seventh and eighth grade students in 5 algebra classes taught by two teachers. One wide-angle camera and 1 or 2 focus group cameras were used to capture video and audio for all sessions. Two researchers recorded field notes of the sessions. The two teachers and the research team jointly developed the technology supported classroom activities.

The goal of the activity was to enact a model of a quadratic function using robot position and motion. The x and y axes of two Cartesian coordinate planes with one foot units were taped to the floor. Five robots were placed equidistant from each other at integer values symmetric at zero facing in the y-positive direction--each robot becoming a moveable point on the coordinate plane. Students entered the y-value into a command line interface (see Figure 1) to tell the robot how far to move in the y direction. The robot moved forward in response to positive values and backward for negative values. Students entered a shift value to align the robot positions with the quadratic function if the y-axis of symmetry was not at zero.

A pair of students, assigned to each robot, entered values into the command line interface and positioned and monitored the robot, pressing the "E" key to initiate robot enactment. The robot first turned and moved to the right or left to enact the shift value before facing in the y-positive direction and moving either backward or forward to enact the y-value. One researcher reviewed the audio and video recordings and field notes to identify a) students making connections between robot movement and mathematical meaning, b) evidence of collaboration, and c) evidence of joint construction of meaning.

Results

Groups completed a total of 17 enactments during the 9 sessions with 7 enactments accurately modeling the quadratic function. Only 3 of the enactments involved shifting the axis of symmetry and all were unsuccessful. Connections made by students between robot motion and mathematical meaning fell into three categories: 1) the position of the robot on the coordinate plane, 2) the forward and backward motion of the robot for positive and negative values, and 3) the relation of the values entered into the computer and motion of the robot. We found little evidence of collaboration or joint construction of meaning. One student generally directed the activities of the others in a group, and connections between the robots and the quadratic function were voiced by the teacher rather than discovered by the students in the course of the activity.

Number Line Activity Environment

The command line interface afforded minimal support for students to make connections between y and shift values and robot movement. To better support these kinds of connections the team envisioned a handheld device interface with an animated display in the mathematical space. To introduce support for collaboration a Hubnet (Wilensky & Stroup, 1999) classroom network of iPod Touch handheld devices was connected to a NetLogo (Wilensky, 1999) server with a robot server extension.

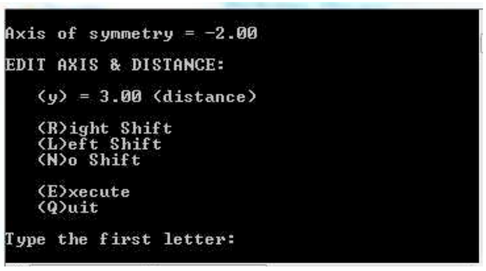

Figure 1. Quadratic Robots Command Line interface.

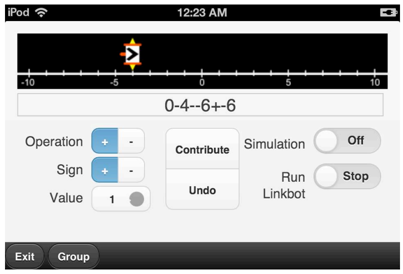

Figure 2: Number Line device interface.

The reassignment of the two pilot study to pre-algebra classes for the 2013-2014 school year, shifted the design focus to robots enacting integer expressions as movement along a number line. Groups of 2 to 4 students jointly construct integer expressions by entering values into the hand-held device interface (see Figure 2). The robot enacted the expression by turning in the direction of the operation and moving forward or backward depending upon the sign of the value. The expression 4+3--2 resulted in placing the robot at 4 on the number line before moving forward 3 units before spinning to face the negative direction and moving backward 2 units. This design built upon pilot study results showing that students talked primarily about robot position as points in the mathematical space and the relation between movement and positive and negative values.

Any device could be switch to simulation mode, causing the robot icon on the device to simulate the enactment of the expression, affording an intermediary opportunity for the student to connect the values they entered to robot motion without affecting other devices. The design encouraged a collective decision to execute the robot enactment by asking every student in the group to predict the end result and the highest and lowest values during the run. The device interface presented a comparison table of predictions and outcomes before setting the collective expression to the endpoint of the run.

Discussion

The pilot study indicated that students primarily discussed the location of the robot as a point in mathematical space and the relation between the direction of motion and the sign of the values they entered. The Number Line activity design refines and extends the opportunity to examine these relations by asking students to predict the outcome of the run and by enacting both the operation and the sign of the value in the motion of the robot. Connecting the robots to a classroom network server supports opportunities for joint meaning construction and collaboration. We think robot movement in combination with an appropriate user interface and network infrastructure can support mathematical meaning construction, both jointly and individually, and provide unique opportunities for collaboration. We implemented the Number Line activity environment in the classrooms of the same two teachers in mid-November, 2013, and have included the preliminary results in the poster.

References

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