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Engaging Elementary and Middle School Students in Robotics through Hummingbird Kit with Snap! Visual Programming Language

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ABSTRACT

The purpose of this paper is to describe how Hummingbird robotics kit with Snap! programing language was used to introduce basics of robotics to elementary and middle school students. Each student in the robotics program built a robot. The robot building process was open ended. Any specific robotics challenge was not provided to the students. Students' knowledge about robots and programming language were measured through pre, post, and delayed posttests. Results indicated that students improved their knowledge about robotics and programing language at the end of the robotics program. Delayed posttest results indicated that the students were able to sustain their improved knowledge two months after the posttest. Formal data about student motivation and interest in STEM learning were not collected; however, it was observed that students expressed interest to participate in more advanced robotics programs in the future.

Keywords: *robotics, programming, Hummingbird Kit, STEM, Snap!*

INTRODUCTION

The past decade has seen the rapid development of robotics curriculums in many schools to improve student success in Science, Technology, Engineering, and Mathematics (STEM) and critical thinking skills (Gura, 2012; Kee, 2011; Ohnishi & Mori, 2014). Studies found a positive correlation between participation in robotics activities and attitudes toward STEM (Pierre & Christian, 2002; Stubbs & Yanco, 2009). Papert (1980) stated that educational robotics has a great potential to improve teaching and learning by allowing students to apply their problem solving and critical thinking skills while constructing robots. Later, Papert (1993) also stated that educational robotics is one of the best vehicles to provide concrete learning opportunities for students.

Some studies indicated the integration of robotics challenges increased students' critical thinking skills, mathematics and science content knowledge (e.g., Hiskens, Peng & Fathy, 2011; Nugent, Barker, Grandgenett, & Adamchuk, 2009). For instance, Blanchard, Freiman and Lirrete-Pitre (2010) investigated the impact of robotics challenges on students' problem solving and critical thinking skills. They observed that students mostly used trial and error problem solving strategy when they worked on robotics challenges. They found that robotics challenges had improved students' problem solving and critical thinking skills. Besides, Nugent et al. (2009) developed an after school program in order to investigate the effects of robotics activities on middle school students' learning of coding, engineering concepts, and attitudes toward STEM. They found that students who did not participate in the after school program did not improve their programming

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knowledge and STEM concepts while students who participated in the after school program improved their programming knowledge and STEM concepts. Likewise, Soares, Ribeiro, Lopes, Leao, & Santos (2011) found that participation in a robotics program positively influenced elementary students' attitudes toward technology.

In another strand, researchers discussed the challenges and strategies for facilitating and promoting interest in STEM careers through extra-curricular activities (Ekong, 2011; Kaya, Deniz, Newley, Yesilyurt, Khalilov, 2016; Pierre and Christian, 2002). Ekong (2011) found that robotics and project-based activities can attract elementary school students to STEM subjects and STEM careers. Kaya et al. (2016) found that extracurricular robotics clubs could increase student interest in STEM careers. Pierre and Christian (2002) developed a competitive robotics program, Robot EAST, to promote STEM through programming and robotics among secondary students. They reported that this program increased student interest in STEM and promoted collaborative work among students.

Several studies explored the impact of robotics programs on STEM interest of minority students and students from lower socioeconomic background. For example, Yuen, Ek and Scheutze (2013) found that participation in robotics programs increased STEM interest of minority students and students from lower socioeconomic background. Ozis, Newley and Kaya (2016) reported that participation in robotics programs helped minority and female secondary students improve their confidence in robotics, develop collaborative working skills, and develop an interest in STEM careers.

The purpose of this study is to describe how we engaged grades 5-8 students in learning coding through a visual block based programming language and building robots to prepare them for future robotics programs. We also aimed to improve their technical and collaborative working skills while they built robots. Although the number of articles about educational robotics is on the rise, we were not able to locate any article exploring the educational affordances of the *Hummingbird Kit* robotics kit with *Snap!* programming language.

METHOD

Participants and Context

Eleven grades 5-8 students participated in the study. The robotics program lasted for seven months. These students were accepted to participate in the robotics program based on their good classroom behavior conduct and their parents' availability to pick them up after school robotics program. Students' academic achievement was not used as a criterion for participation.

The robotics program was offered at a school located in the southwest region of the United States. The school is a K-12 state sponsored tuition free public charter school with STEM emphasis. All students in the school qualified for free and reduced lunch. The school has high percentage of English language learners (32.7%) and minority students (Table 1). Demographics of our robotics team reflects the overall school diversity. The school has a history of involvement in FIRST Robotics competitions (FIRST, 2016).

Table 1. Percentage of students by ethnicity

Ethnicity	Percentages
American Indian	.99%
Asian	3.3%
Black/African American	46.2%
Hispanic/Latino	15.51%
Multiple Race	.66%
Native Hawaiian	.33%
White	33%

Robotics Kit and Programming Language

Hummingbird is an educational robotics kit aiming at students ages 8 and up. It includes DC, servo and vibration motors, several sensors, and LED lights with different complementary attachments (Figure 1).

KIT CONTENTS — Buy additional parts at hummingbirdkit.com/buy

Components	Controller	Base Kit	Premium Kit	Classroom Kit
Duo Controller	x1	x1	x1	x4
5V/2A Power Cable	x1	x1	x1	x4
USB Cable	x1	x1	x1	x4
Terminal Tool	x1	x1	x1	x4
Standoff	x4	x4	x4	x16
Single Color LED		x4	x4	x12
Tri-Color LED		x2	x2	x8
Servo		x2	x4	x10
Servo Extension Cable		x1	x2	x6
Gear Motor			x2	x4
Wheel Adapter			x2	x4
Plastic Block Adapter			x2	x4
Vibration Motor			x2	x4
Light Sensor		x1	x1	x4
Temperature Sensor		x1	x1	x4
Distance Sensor			x1	x2
Sound Sensor			x1	x2
Rotary Sensor			x1	x2

Figure 1. Hummingbird Kit Contents (Hummingbird robotics kit, 2016)

The Hummingbird controller has clearly marked ports by number and component, the connection port to connect to the computer, the port for additional motor and servo power, and an easy grip screwdriver for connecting components to the ports (Figure 2).

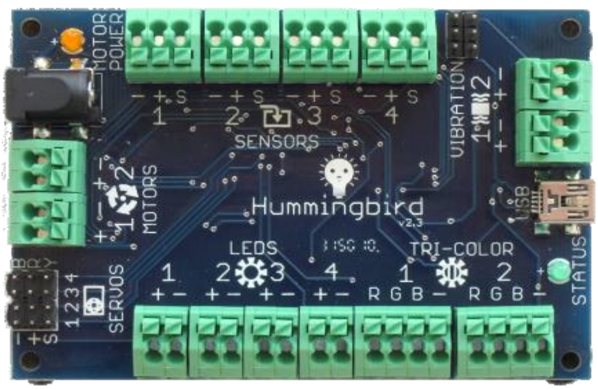

Figure 2. Hummingbird Controller (Teacher Guide - Hummingbird Robotics Kit, 2016)

Before the students started building robots, they explored programming with Snap! 4.0 (Snap, 2015). This language employs a simple "drag-and-drop" interface. The interface window has five regions (Figure 3):

- *ToolBar:* Comprised of file options, window preferences, script play, pause, and stop applications.
- *Palette:* Contains the block categories color-coded by function.
- *Scripting Area:* Space to drag the blocks and connect them to build programming scripts.
- *Stage:* modify, and evaluate the script before applying the program to the robot.
- *Sprite Corral:* Manage different Sprites, or icons, that run each program.

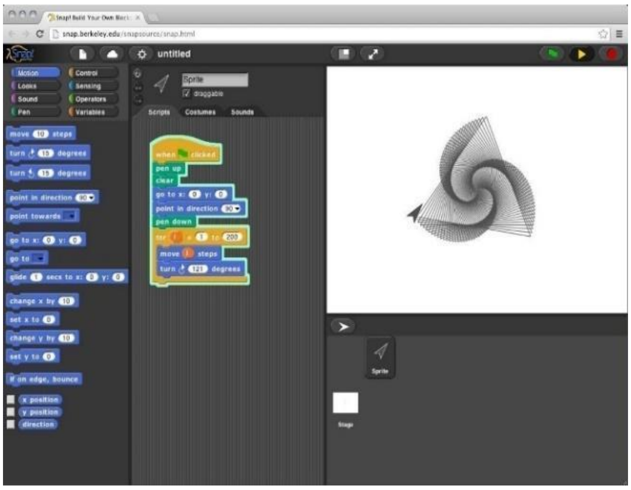

Figure 3. Snap! 4.0 Interface window (Snap, 2016)

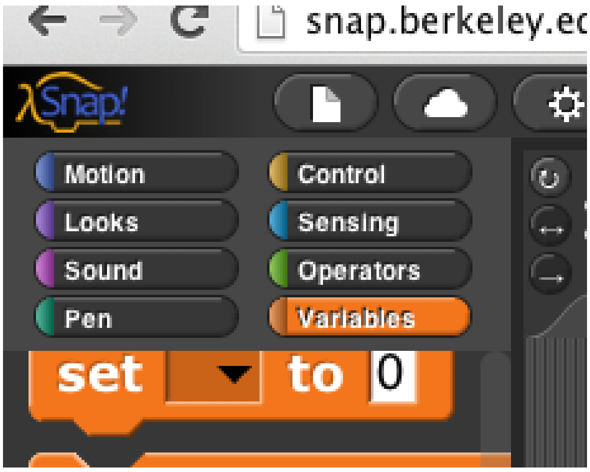

Figure 4. Eight categories of Snap! Programming (Snap, 2016)

The palette has eight categories (Figure 4):

- *Motion:* Blocks for servos, various motors, and options for movement direction.
- *Looks:* Blocks for LED and TRI-LED lights with alternatives for sprite appearance and speech.
- *Sound:* Blocks to create messages or sounds for the robot.
- *Pen:* Blocks for color, thickness, and transparency of Sprite pen.

- *Control:* Hat Blocks that initiate scripts, and C-Shaped Blocks that direct how many times to complete an action.
- *Sensing:* Blocks for various sensors associated with the Hummingbird Kit.
- *Operator:* Blocks for conditional scripts, equations, and predicates.
- *Variables:* Facilitates designing and naming your own blocks.

Figure 5. 6th and 7th grade students programming with Snap!

In this robotics program, students learned Snap! programming language and they applied their knowledge in building robots (Figure 5, 6, 7, 8 and 9). Snap! programming language is a useful tool for transitioning students into other programming languages with greater complexity, such as Java. Wagner et al. (2013) used a similar drag and drop language to prepare high school students to learn Java programming language. We think that Hummingbird kit with Snap! programming language has a potential to increase student interest in robotics and get them ready for more advanced programming languages and robotics designs.

Figure 6. 5th and 6th grade students constructing robots.

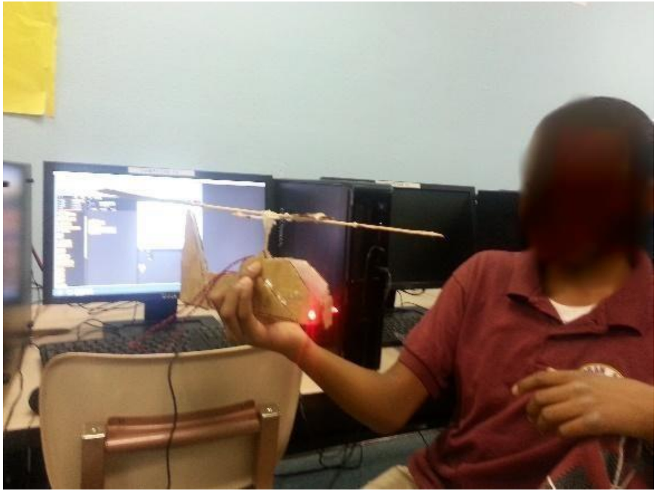

Figure 7. 7th grade student creating with the Hummingbird Kit.

Figure 8. 5th grade student creating with the Hummingbird Kit.

Figure 9. 5th grade student creating with Hummingbird kit.

Assessment

Each student in the robotics program built a robot with some help from other students. The robot building process was open ended. We did not provide them with a specific robotics challenge. Students used Hummingbird kit contents and recyclable materials to design their robots in a noncompetitive environment. Their robots were capable of performing acts such as moving motors forwards and backwards, turning in angles, vibrating, and using sensors and LED lights.

We measured students' knowledge about robots and programming language at the beginning and at the end of the robotics program through a 13-item test including open-ended, multiple-choice, and true or false question formats (Appendix A). We also administered the same test 2 months after the robotics program.

RESULTS AND DISCUSSIONS

All of our students successfully designed, coded, and built their own robots. They presented their robots to an audience including parents, teachers, and other students. They explained how they performed certain actions with the help of their programming language knowledge. Students were able to explain the interaction between Hummingbird kit (hardware) and Snap! programming language (software) when they showcased their robots to the audience.

Table 2 shows pretest, posttest and delayed posttest results. Our results indicated that students improved their knowledge about robotics and programming language at the end of the robotics program. Our delayed posttest results indicated that our students were able to sustain their improved knowledge two months after the posttest. Pretest scores ranged from 2 to 7 with a mean of 4.4 while post scores ranged from 7 to 12 with a mean of 9.9. Therefore, there was a dramatic increase in participants' knowledge and skills at the end of the program. We think that building robots with Hummingbird kit coupled with Snap! programming language were effective in improving students' knowledge and skills about robotics and programming. We did not collect formal data about student motivation and interest in STEM learning, but we observed that students expressed interest to participate in more advanced robotics programs in the future.

Table 2. Statistical scores for pretest, posttest and delayed posttest

	Mean	Maximum	Minimum	Range	Standard Deviation
Pre-test	4.4	7.00	2.00	5.00	1.43
Post-Test	9.91	12.00	7.00	5.00	1.97
Delayed Post Test	9.00	11.00	6.00	5.00	1.61

Robotics offers an innovative way to teach problem-solving, critical thinking and basic programming concepts. Robots provide a unique method and hands-on approach in teaching programming. In this robotics program, students learned basics of Snap! programming language to control their robots. Students received instant feedback while they programmed their robots. Students immediately observed how their programming controlled the actions of their robots. We believe that Hummingbird kit with Snap! programming language is a valuable tool to

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introduce robotics to elementary and middle school students. This particular kit allows the integration of engineering design, robotics, and programming language. This kit provides certain affordances: (a) it is more affordable compared to other commercially available robotics kits, (b) it does not require prior programming knowledge, (c) drag and drop nature of Snap! visual programming language makes it more developmentally appropriate for elementary and middle school students than text-based programming languages, (d) it is compatible with multiple programming languages, (e) it allows students to come up with unlimited number of robotics designs from recyclable materials by encouraging their creativity and imagination.

Robotics programs increase student interest in STEM (Nugent et al., 2009; Ozis et al., 2016), but offering after school robotics programs present certain challenges. These challenges include finding qualified robotics teachers, the cost involved purchasing the robotics kit, student pick-up after the robotics program, and insufficient parent involvement. Most schools do not have teachers qualified to teach after school robotics programs. Availability of such experienced teachers in socially and economically disadvantaged schools is even more limited. The first author had experience in offering after school robotics programs, particularly in encouraging participation of female and minority students. We were able to purchase the robotics kit with a grant from Arizona Technology in Education Association (AzTEA) and Century Link. Even though we had a large number of students interested in participating the robotics program, we were able to accept only 11 students because our parents were not able to pick them after the robotics program. We offered this program at a school located in a socially and economically disadvantaged community. Most of our parents did not speak English fluently. We were not able to effectively communicate with our parents to get them more engaged in the robotics program. Robotics programs offered in schools located in more affluent neighborhoods may not have challenges associated with cost, student pick-up, and parent involvement. More research must be done by considering large populations and different students' level.

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APPENDIX A

Written questions

1. Detects the sound level of the surrounding area.
2. A motor that can rotate 360 degrees forward or backward (-100,100).
3. Drag and drop programming software.
4. Detects how far away something is from 3 inches to 36 inches or 8 centimeters to 60 centimeters.
5. Detects the air temperature in Fahrenheit and Celsius.

Multiple choice questions

1. A small motor that shakes. You can control how quickly or slowly. (Intensity 0 to 100)

a. Vibration Motor
b. Distance Sensor
c. Light Sensor
d. Motor

2. A light bulb that can shine all red, green, or blue or a combination of all three colors.

a. Tri-Color LED
b. Reporter Block
c. Motor
d. Single Color LED

3. Tells when your script should be carried out.

a. Motor
b. Reporter Block
c. Hat Block
d. Command Block

4. Oval shaped block that reports the value of sensors or coordinate positions.

a. Hat Block
b. Tri-Color LED
c. Command Block
d. Reporter Block

True/False questions

1. Command Block → Tells when your script should be carried out.

True False

2. Servo → A motor that can turn various degrees from 0 to 180.

True False

3. Single Color LED → A light bulb that shines one color at different brightness levels.

True False

4. Light Sensor → Detects the sound level of the surrounding area.

True False