DEVELOPING COMPUTATIONAL THINKING THROUGH A VIRTUAL ROBOTICS PROGRAMMING CURRICULUM

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The Role of Robotics in CS for All

With the policy push of CS for All, school districts are searching for rich CS learning opportunities.

Often, robotics comes up as a popular option. But...

...do robotics programs offer engaging opportunities for all students to learn programming, and in a way that is generalizable?
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Often, robotics comes up as a popular option. But...

...do robotics programs offer engaging opportunities for all students to learn programming, and in a way that is generalizable?
Computational Thinking definitions include:

“an approach to solving problems in a way that can be solved by a computer...a problem solving methodology that can be transferred and applied across subjects.”

(Barr & Stephenson, 2011)
From Robotics to Computational Thinking

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Virtual Robotics Programming Curriculum

- **Graphical programming language** reduces cognitive demand for novice programmers by removing some syntax requirements. (Robins, Rountree, & Rountree, 2010)

- **Dynamic challenges** change surface-level details of problem, requiring the development of a generalizable algorithmic solution. (Barnett & Koslowski, 2002; Gick & Holyoak, 1983)

- **Scaffolded lessons** provided multiple opportunities to engage with CS concepts, and re-use earlier semantic “chunks” of code. (Brennan & Resnick, 2012)
CS and Robotics...for All?

Elective Robotics Clubs/Teams
- Optional, “For Some”
- Predominately male (60-70%)
- Self-selected, higher STEM interest
- Strong pathways to CS+STEM

General Education Robotics Classes
- General Ed courses, “For All”
- Typically gender balanced
- Non-elective, lower STEM interest
- May under-emphasize programming

Can non-elective robotics motivate continued involvement in programming, particularly for women?

(Benitti, 2012; Ericson, et al., 2008; Melchior, et al., 2005)
## Study Design and Methods

### Research Questions

<table>
<thead>
<tr>
<th>Can general computational principles, learned in a robotics context, be applied in dissimilar contexts?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Can non-elective robotics motivate continued involvement in programming, particularly for women?</td>
</tr>
</tbody>
</table>

### Sample

<table>
<thead>
<tr>
<th>N=136</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Grades</th>
</tr>
</thead>
<tbody>
<tr>
<td>6th, 8th</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>48% Female</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Ethnicity</th>
</tr>
</thead>
<tbody>
<tr>
<td>78% White</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>F-R Lunch</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Instructional Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>~30 days</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pre-Post</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Programming Assessment (Form A, B)</td>
</tr>
<tr>
<td>• Motivation Survey</td>
</tr>
</tbody>
</table>
## Virtual Robotics Curriculum Units

### Methods
- Students grouped by unit progress:
  - **Basic Movement** ($n=39$)
  - **Sensors** ($n=40$)
  - **Program Flow** ($n=57$)

<table>
<thead>
<tr>
<th>Unit</th>
<th>Chapter</th>
<th>Challenge</th>
<th>Programming Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basic Movement</td>
<td>Moving Forward</td>
<td>Static</td>
<td>Sequences</td>
</tr>
<tr>
<td></td>
<td>Turning</td>
<td>Static</td>
<td>Sequences</td>
</tr>
<tr>
<td>Sensors</td>
<td>Forward Until Near</td>
<td>Dynamic</td>
<td>Sequences, Conditions</td>
</tr>
<tr>
<td></td>
<td>Turn for Angle</td>
<td>Static</td>
<td>Sequences, Conditions</td>
</tr>
<tr>
<td></td>
<td>Color Sensor</td>
<td>Dynamic</td>
<td>Sequences, Conditions</td>
</tr>
<tr>
<td>Program Flow</td>
<td>Loops</td>
<td>Dynamic</td>
<td>Sequences, Conditions, Iteration</td>
</tr>
<tr>
<td></td>
<td>If-Else</td>
<td>Dynamic</td>
<td>Sequences, Conditions, Iteration</td>
</tr>
<tr>
<td></td>
<td>Repeated Decisions</td>
<td>Dynamic</td>
<td>Sequences, Conditions, Iteration</td>
</tr>
</tbody>
</table>
Programming Assessment

Materials
Programming assessment in 3 sections ($\alpha = .84$):

- (6) Robotics Programming
- (7) General Programming
- (12) Computational Thinking

<table>
<thead>
<tr>
<th>Context</th>
<th>Same</th>
<th>Similar</th>
<th>Dissimilar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robotics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sequences</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conditions</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Iteration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sequences</td>
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<td>Conditions</td>
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<td>Iteration</td>
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<td>CT</td>
<td></td>
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<td></td>
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<tr>
<td>Sequences</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Conditions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Iteration</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Sample Assessment Items

Three boxes are equally spaced in a row. A robot is programmed to drive from “Start” to each box and move the box to the robot’s left.

(Start) → (Box 1) → (Box 2) → (Box 3)

(Robot’s path viewed from above)

This program should perform the behavior described above.

Line 1: Repeat these commands 3 times:
Line 2: 
Line 3: Close the claw
Line 4: Turn 90 degrees to the left
Line 5: Open the claw
Line 6: Turn 90 degrees to the right

6. What command needs to be placed in the loop at line 2?

Select one:

- No additional command is necessary
- A moving forward command
- A turn 90 degrees to the left command
- A repeat 3 times command

$\alpha = .64$
Programming Assessment

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- (6) Robotics Programming
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Sample Assessment Items

Scenario A: Subway Systems
A subway train counts the number of rotations a front wheel makes, and uses that number to know when to stop. It does this by comparing the current number of rotations on the wheel to the number of rotations needed to reach its destination.

The number of rotations starts at zero, and counts upward as the train moves.

14. Select the answer below that would make the train stop in the right place.

The train runs until (______________), then stops.

Select one:
- O Current wheel rotations $\geq$ Number of rotations needed to reach destination
- O Current wheel rotations $< <$ Number of rotations needed to reach destination
- O Current wheel rotations + Number of rotations needed to reach destination $>$ 1
- O Current wheel rotations – Number of rotations needed to reach destination $= $ TRUE

$\alpha = .68$
## Programming Assessment

### Materials
Programming assessment in 3 sections ($\alpha = .84$):

- **(6) Robotics Programming**
- **(7) General Programming**
- **(12) Computational Thinking**

### Sample Assessment Items

**Personal fitness devices use electronic sensors to continuously monitor and track data about a user’s health such as steps taken, calories burned, and heart rate.**

The BP-Sure company is developing a new feature for their fitness device that also measures the user’s blood pressure, using sensors that detect a user’s heartbeat. When the heart pushes blood through the arteries, the device records “Pressure 1”, and when the heart is resting, the device records “Pressure 2”.

- **Adjustable wristband**
- **Pressure 1**
- **Pressure 2**

The device can determine if a user’s blood pressure is in the Normal, Medium or High range, by comparing blood pressure readings to the chart below.

Use the chart below to answer questions #19, #20 and #21.

<table>
<thead>
<tr>
<th>Blood Pressure</th>
<th>Pressure 1 ($p_1$)</th>
<th>Pressure 2 ($p_2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal BP</td>
<td>$p_1 \leq 120$ AND</td>
<td>$p_2 \leq 80$</td>
</tr>
<tr>
<td>Medium BP</td>
<td>$121 \leq p_1 \leq 139$ AND</td>
<td>$81 \leq p_2 \leq 89$</td>
</tr>
<tr>
<td>High BP</td>
<td>$p_1 &gt; 140$ OR</td>
<td>$p_2 &gt; 90$</td>
</tr>
</tbody>
</table>

A new programmer on the team writes the following series of steps to determine the display when a user is in the “Normal BP” range:

- **Line 1** IF ($p_1 \leq 120$ AND)
- **Line 2** $p_1 \leq 121$ AND
- **Line 3** $p_2 \leq 80$ AND
- **Line 4** $p_2 \leq 81$
- **Line 5** THEN set display = “Normal BP”

Which lines can be removed to make the code more efficient, while not changing the code output?

Select one:
- O Line 1 and Line 4
- O Line 2 and Line 3
- O Line 2 and Line 4
- O Line 1 and Line 3

$\alpha = .65$
Results: Programming Assessment

Can general computational principles, learned in a robotics context, be applied in dissimilar contexts?

Results

• Larger gains in later units (Sensors & Program Flow); similar to pilot study

• However, only Program Flow showed significantly larger gains on the most distant (Computational Thinking) assessment items

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**Results**
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- However, *only Program Flow* showed significantly larger gains on the most distant (Computational Thinking) assessment items

*ns* = not significant; *p* < .05, **p** < .01, ***p*** < .001

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Results: Programming Assessment

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Results: Gender Differences

Results
- No differences by gender at pre
- Girls show significantly larger gains on all three sections of the programming assessment
Motivation Survey

Continued Participation in CS and STEM

• Middle- and high-school **interest** can be predictive of selection of college courses and major (Harackiewicz & Hulleman, 2010)

• Students **identity** as “someone who does STEM” can influence their continued engagement in STEM experiences (Aschbacher, Li & Roth, 2010)

• Belief in ability to be successful, or **competency beliefs** correlates with perseverance; particularly for women in male dominated STEM fields (Zeldin & Parajes, 2000)

Motivation Items

• (4) Interest
• (4) Identity
• (4) Competency Beliefs

E.g. “After a really interesting programming activity is over, I look for more information on it” $\alpha = .79$

E.g. “My friends think of me as a programming person” $\alpha = .85$

E.g. “I am sure that I can do well on a programming assignment in my class” $\alpha = .83$
Results: Motivation Survey

**Results**

- Overall, pre-post declines on all motivational measures
- No differences in any motivation construct by gender
- However, significant variation by unit, with different patterns by construct

Can non-elective robotics motivate continued involvement in programming, particularly for women?

[Graph showing estimated mean gains for different constructs: Interest, Basic Movement, + Sensors, + Program Flow.](#)
Results: Motivation Survey

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Discussion & Limitations

Limitations

• No experimental control or random assignment to condition; cannot directly address causality of curricular exposure or units reached.
• Unobserved differences in implementation may contribute to variation in learning gains.

Can general programming principles, learned in a robotics context, be applied in dissimilar contexts?

• Abstract computational principles can be learned in a very concrete robotics context.
• Later units were associated with larger gains on the most contextually dissimilar items.

Can non-elective robotics motivate continued involvement in programming, particularly for women?

• Overall, girls outperform boys on all section of the assessment
• Interesting variation in motivation by unit; however no differences by gender

Thank you!

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