DEVELOPING COMPUTATIONAL THINKING THROUGH A VIRTUAL ROBOTICS PROGRAMMING CURRICULUM

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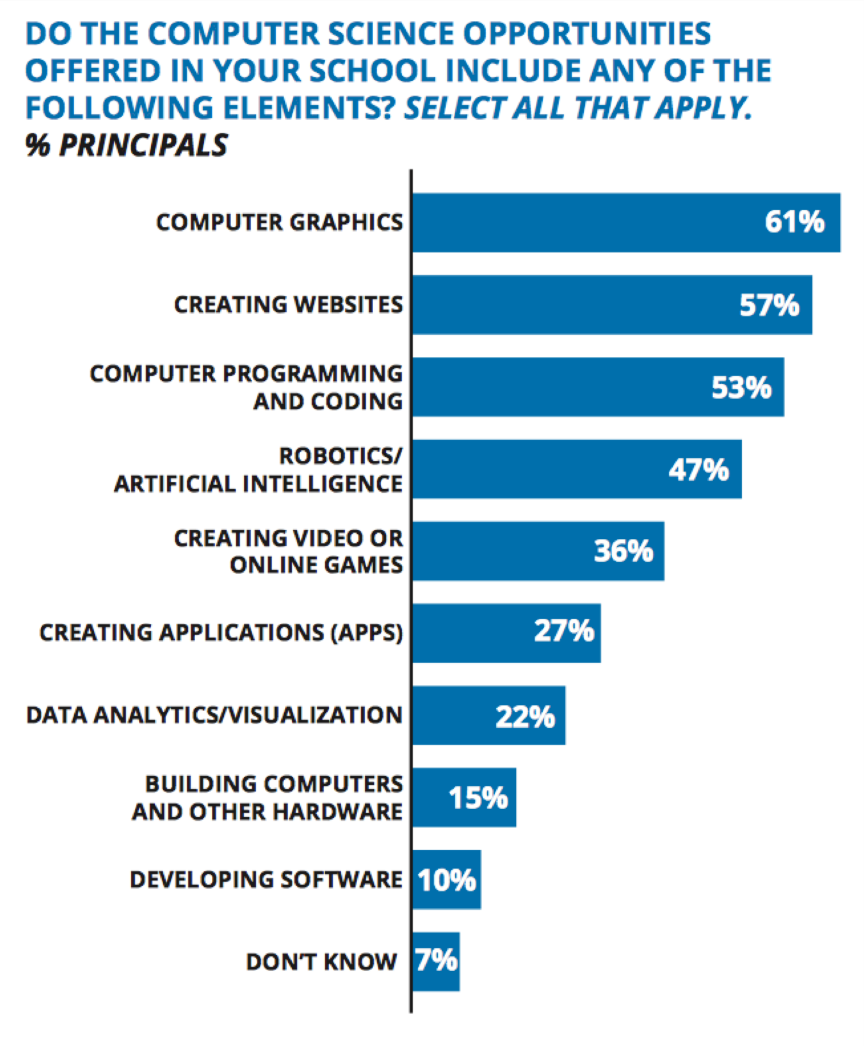
The Role of Robotics in CS for All



(Google Inc. & Gallup, 2015)

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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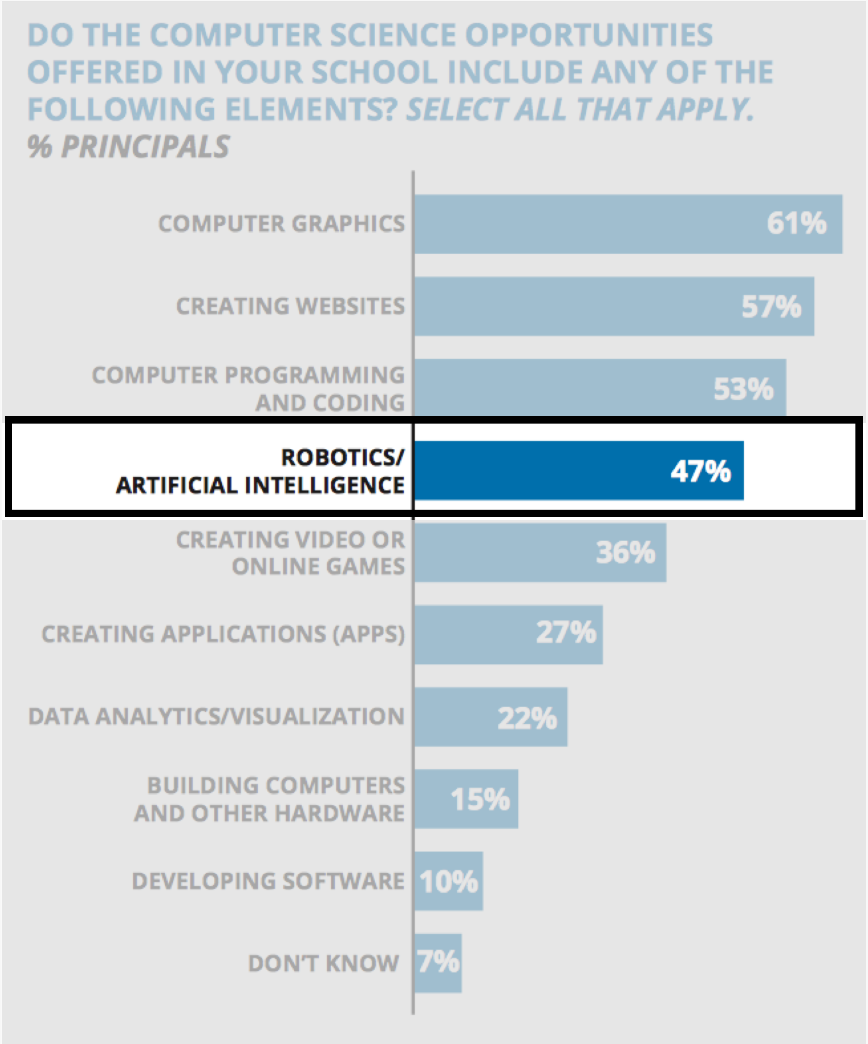

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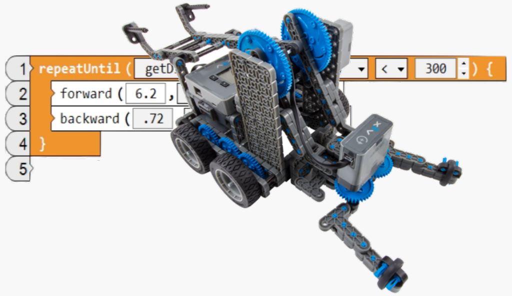
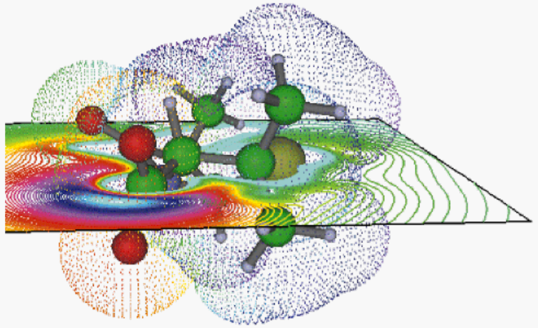
From Robotics to Computational Thinking

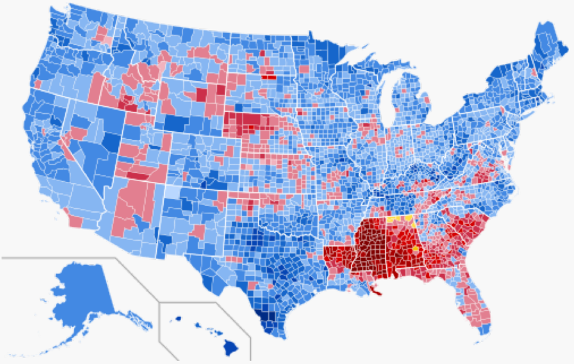
Computational Thinking definitions include:

*“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)







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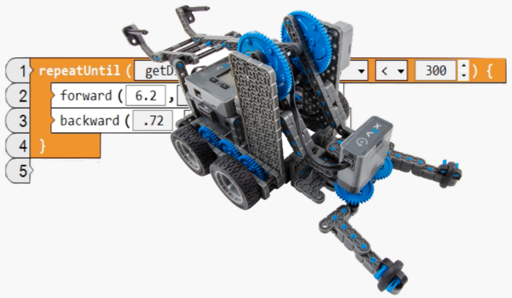
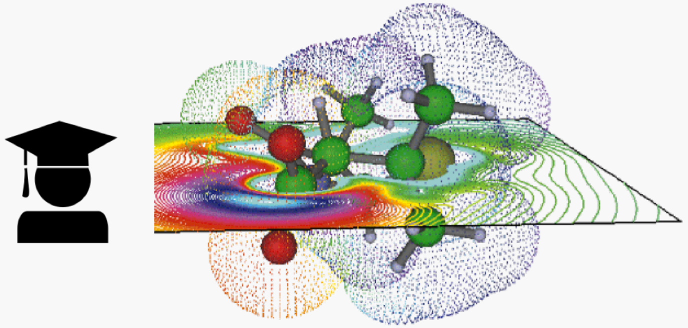
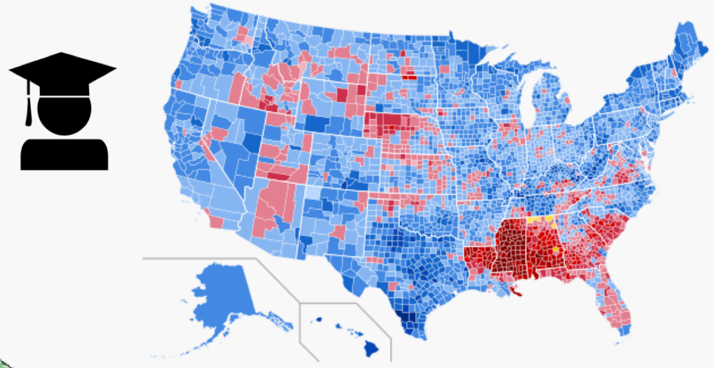
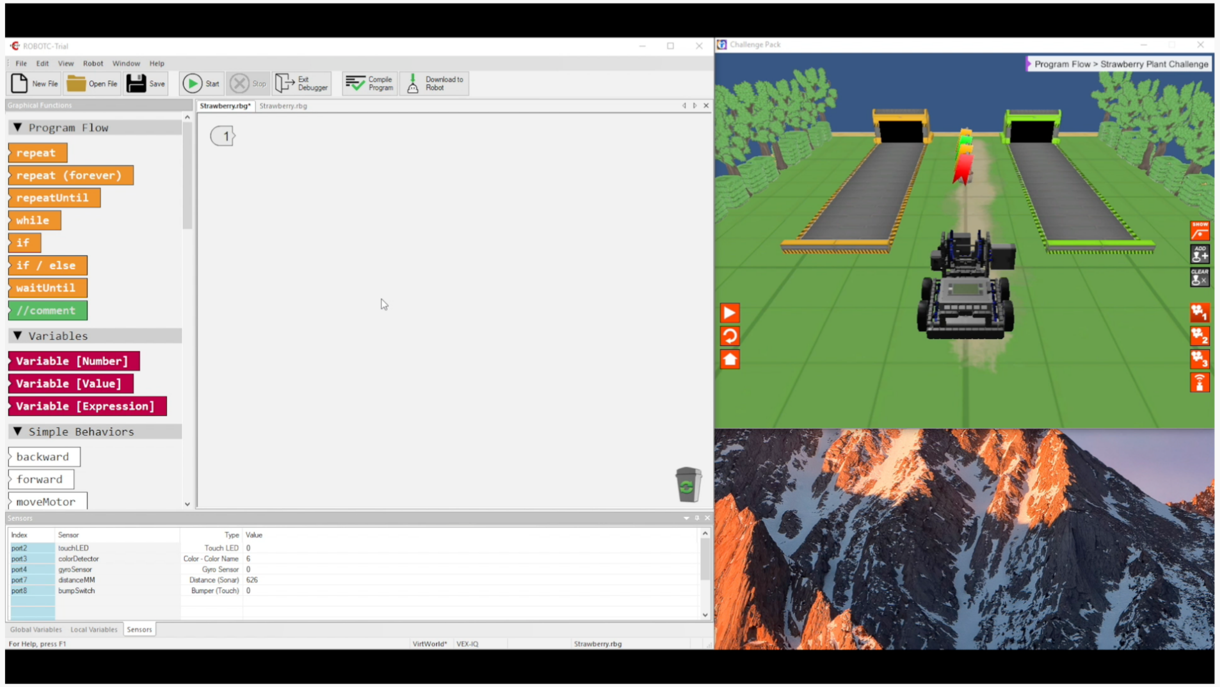






Can general computational principles, learned in a robotics context, be applied in dissimilar contexts?

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	Can general computational principles, learned in a robotics context, be applied in dissimilar contexts? Can non-elective robotics motivate continued involvement in programming, particularly for women?
Sample	N=136
Grades	6th, 8th
Gender	48% Female
Ethnicity	78% White
F-R Lunch	5%
Instructional Time	~30 days
Pre-Post	• Programming Assessment (Form A, B) • Motivation Survey

Virtual Robotics Curriculum Units

Methods

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

Unit	Chapter	Challenge	Programming Concepts
Basic Movement	Moving Forward	Static	Sequences
	Turning	Static	Sequences
Sensors	Forward Until Near	Dynamic	Sequences, Conditions
	Turn for Angle	Static	Sequences, Conditions
	Color Sensor	Dynamic	Sequences, Conditions
Program Flow	Loops	Dynamic	Sequences, Conditions, Iteration
	If-Else	Dynamic	Sequences, Conditions, Iteration
	Repeated Decisions	Dynamic	Sequences, Conditions, Iteration

Programming Assessment

Materials

Programming assessment in 3 sections (α = .84):

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

	Context		
	Same	Similar	Dissimilar
Robotics			
Sequences			
Conditions			
Iteration			
General			
Sequences			
Conditions			
Iteration			
CT			
Sequences			
Conditions			
Iteration			

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.

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

α = .64

Programming Assessment

Materials

Programming assessment in 3 sections (α = .84):

- (6) Robotics Programming
- (7) General Programming
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	Context		
	Same	Similar	Dissimilar
Robotics			
Sequences			
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CT			
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Iteration			

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 >= 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

α = .68

Programming Assessment

Materials

Programming assessment in 3 sections (α = .84):

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

	Context		
	Same	Similar	Dissimilar
Robotics			
Sequences			
Conditions			
Iteration			
General			
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CT			
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Iteration			

Sample Assessment Items

Personal fitness devices use electronic sensors to continuously monitor and track data about a user's heath 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".

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.

Blood Pressure	Pressure 1 (p1)		Pressure 2 (p2)
Normal BP	p1 <= 120	**AND**	p2 <= 80
Medium BP	121 <= p1 <= 139	**AND**	81 <= p2 <= 89
High BP	p1 >= 140	**OR**	p2 >= 90

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 (p1  <=  120 AND
(Line 2)       p1  <=  121 AND
(Line 3)       p2  <=  80  AND
(Line 4)       p2  <=  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

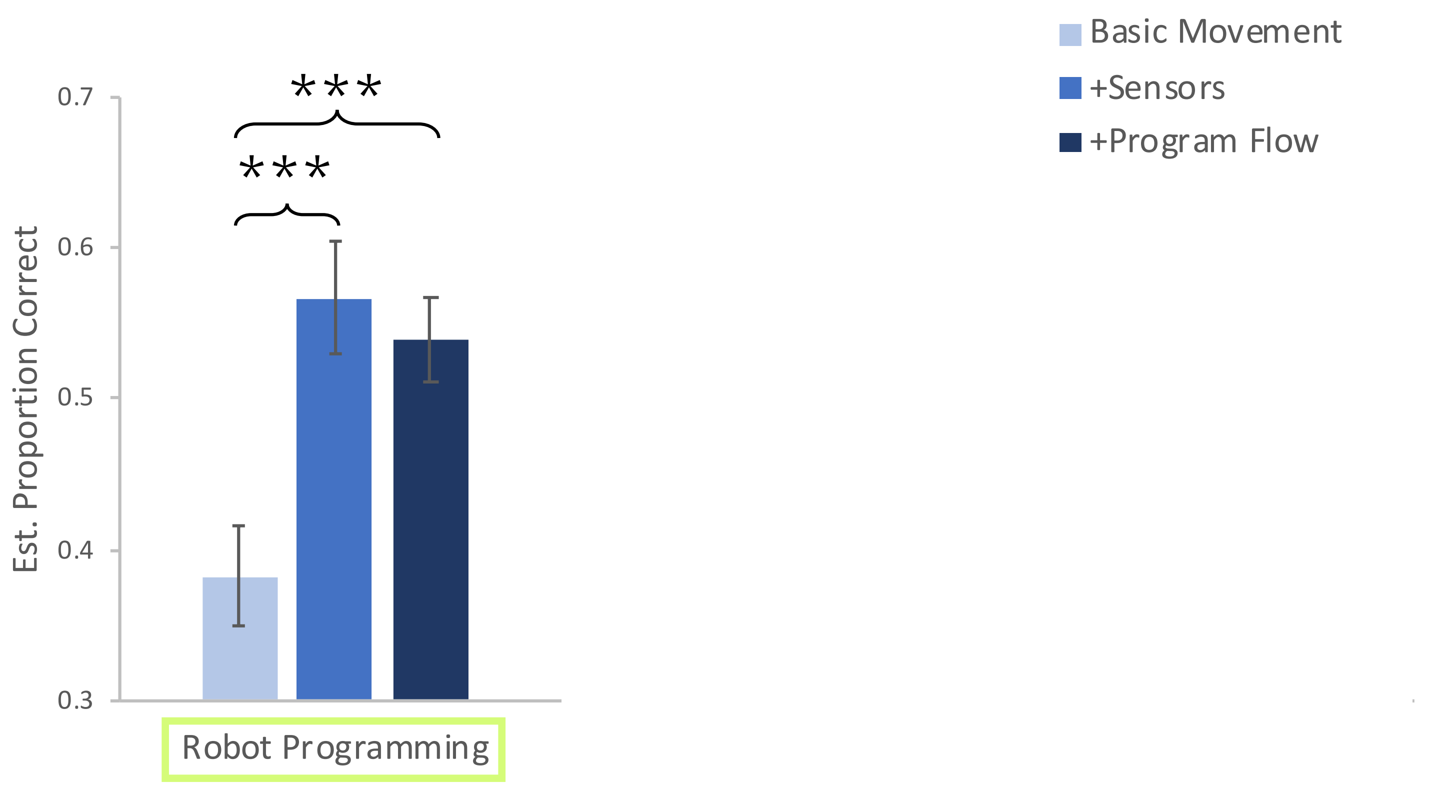
α = .65

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



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

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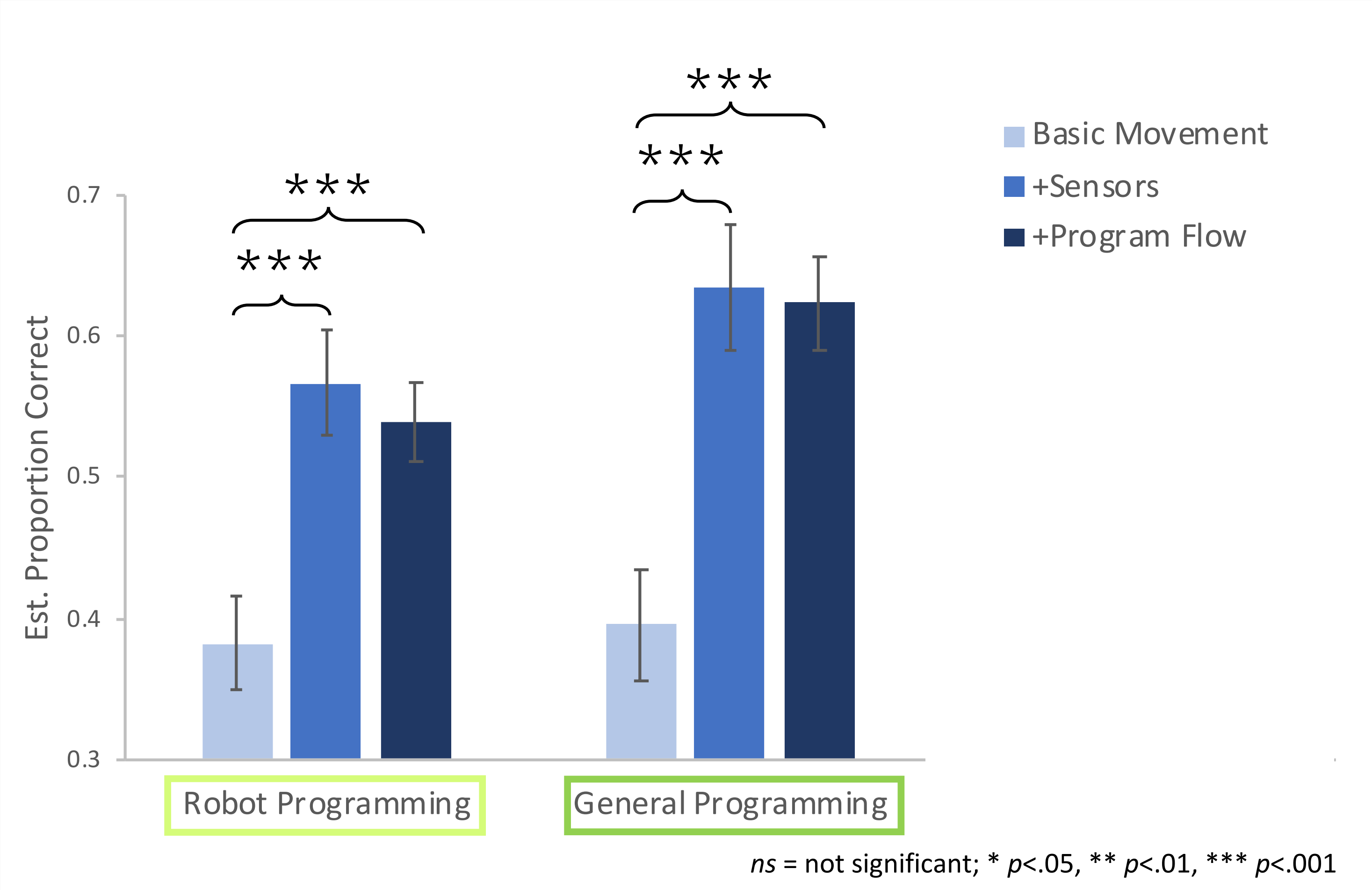

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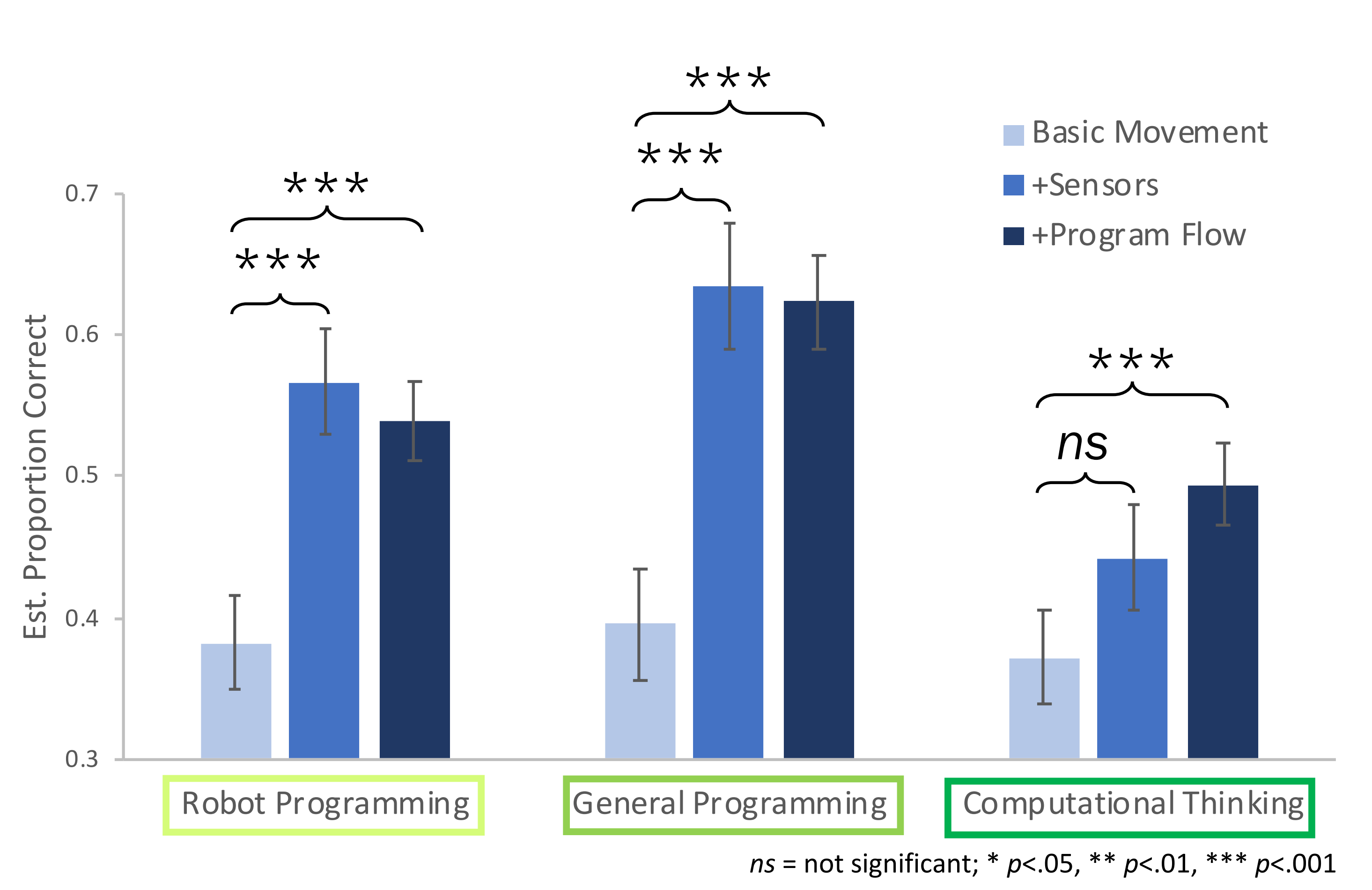
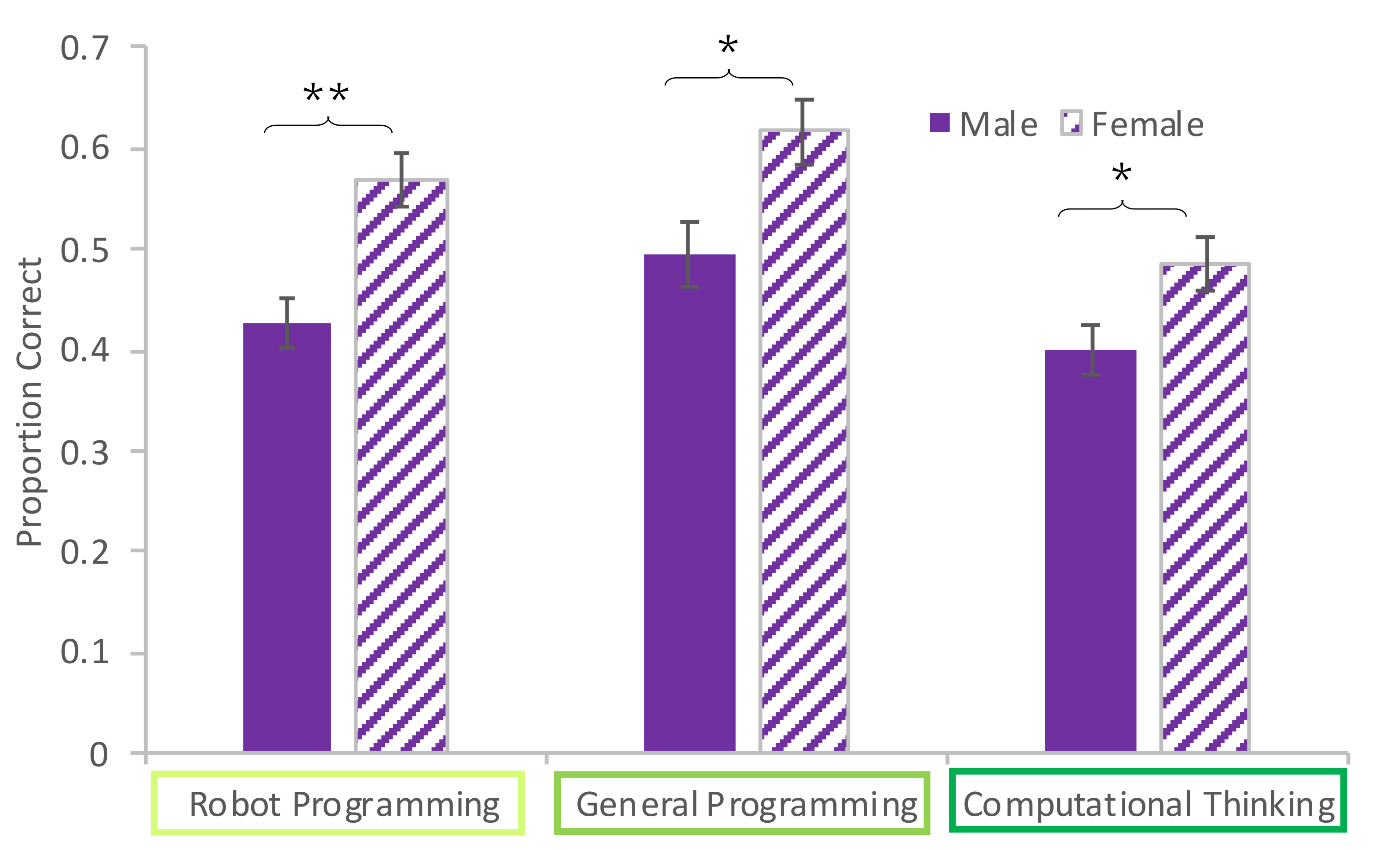


Results: Gender Differences

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

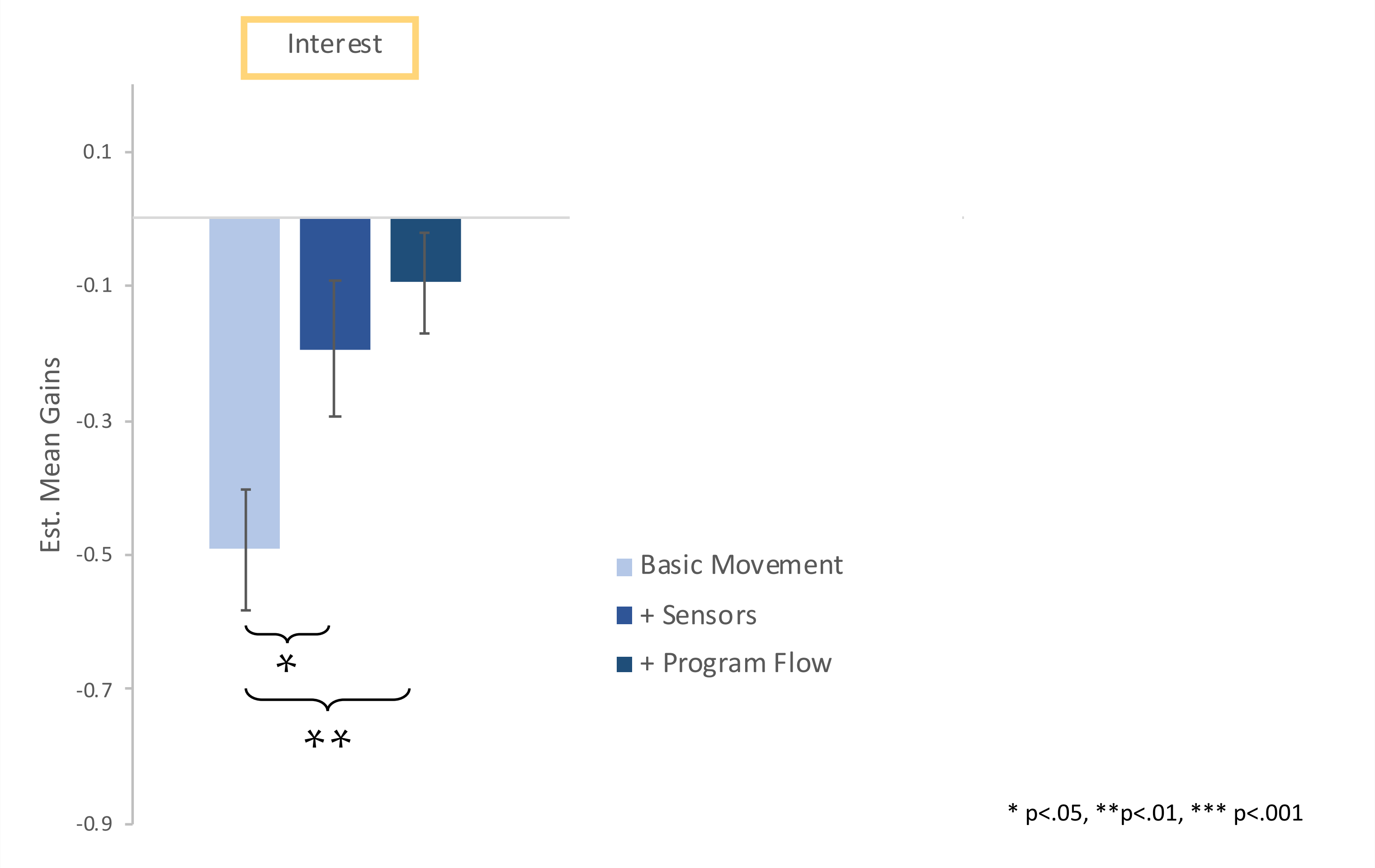
Item	Example	Reliability
Interest	E.g. "After a really interesting programming activity is over, I look for more information on it"	α = .79
Identity	E.g. "My friends think of me as a programming person"	α = .85
Competency Beliefs	E.g. "I am sure that I can do well on a programming assignment in my class"	α = .83

Results: Motivation Survey

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

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



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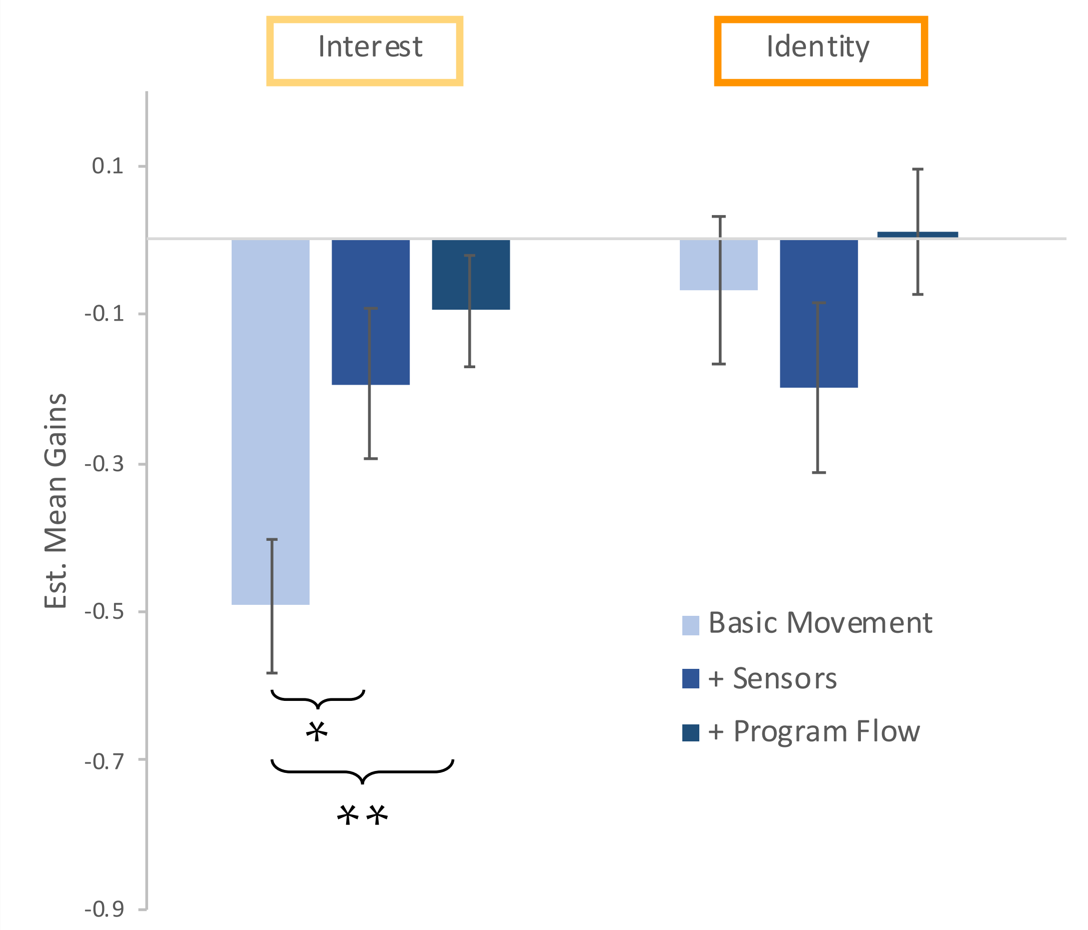

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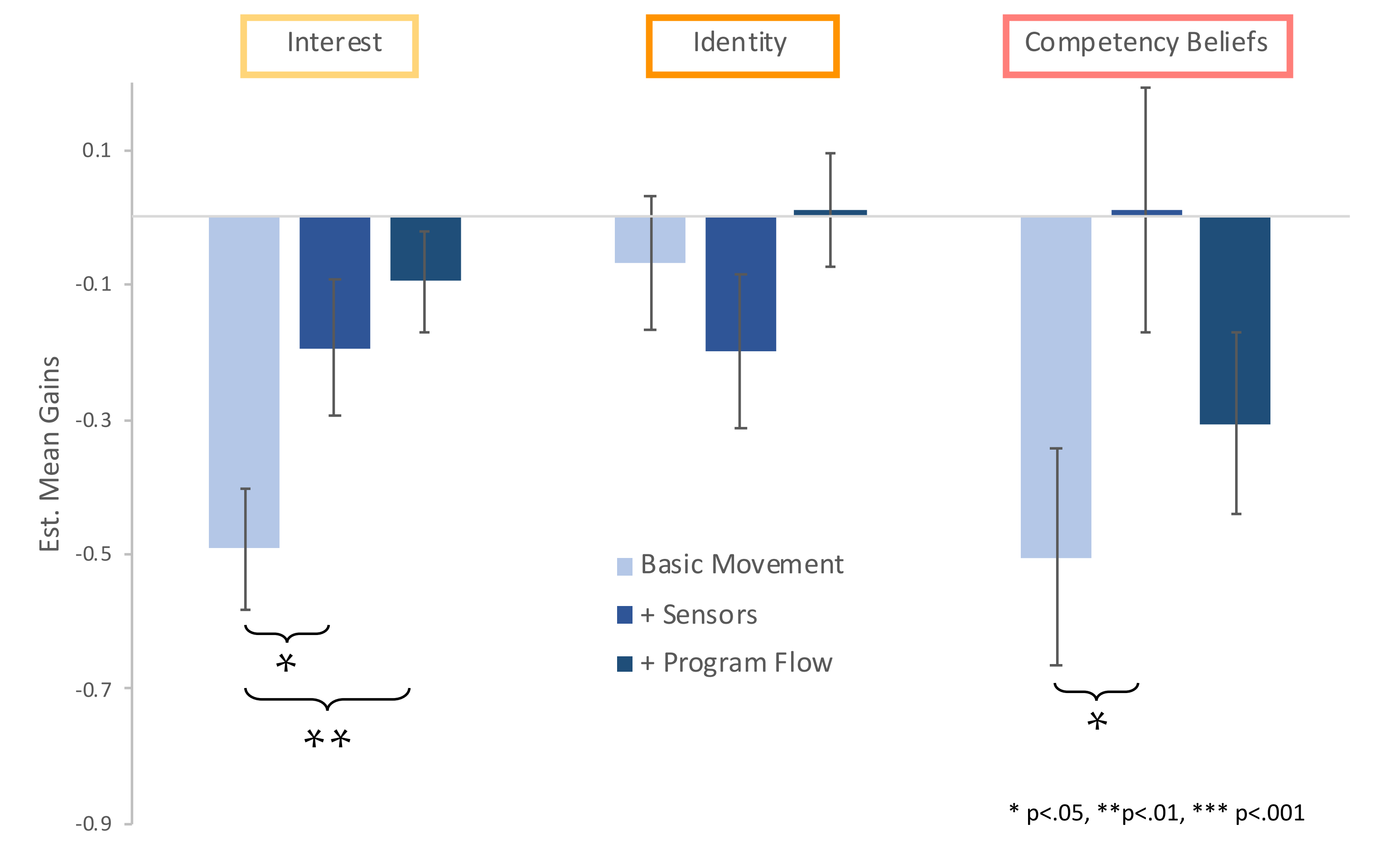

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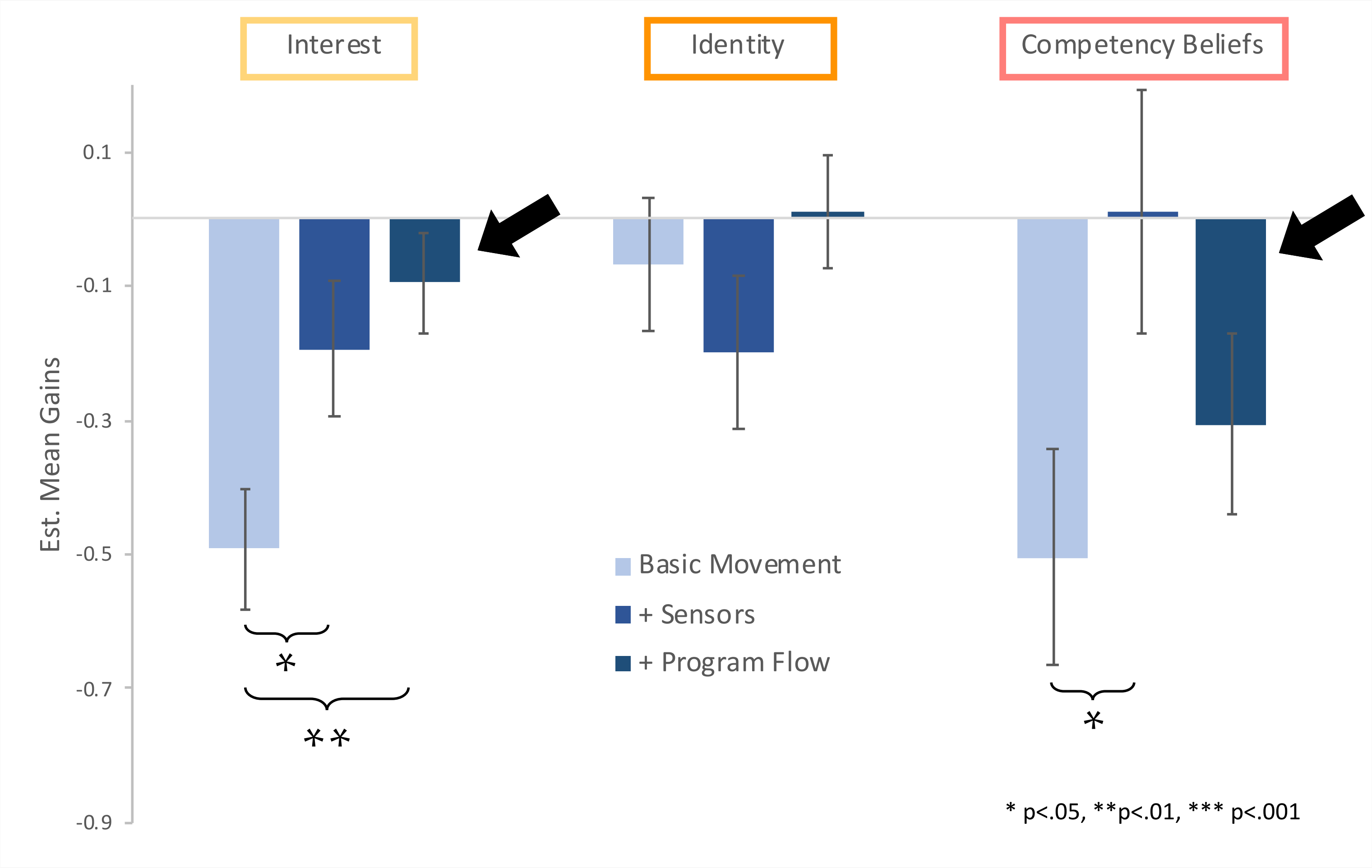

Discussion & Limitations

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

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.

Thank you!

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