HINTS

An Evaluation of the Impact of Automated Programming Hints on Performance and Learning

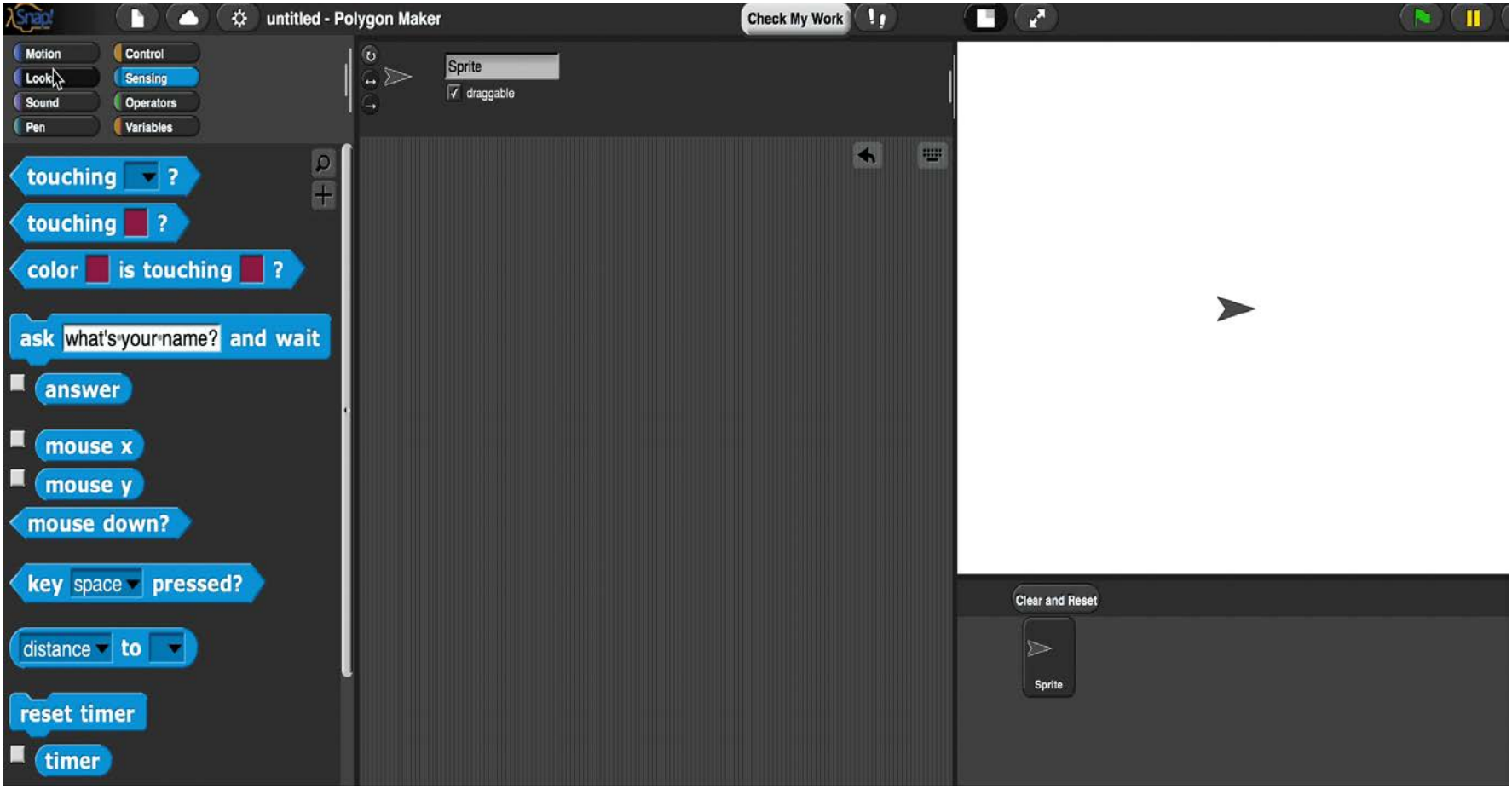
Samiha Marwan
samarwan@ncsu.edu

Dr. Joseph Williams
williams@cs.toronto.edu

Dr. Thomas Price
twprice@ncsu.edu

- Imagine Jill (a student) working on his first programming homework on Snap.

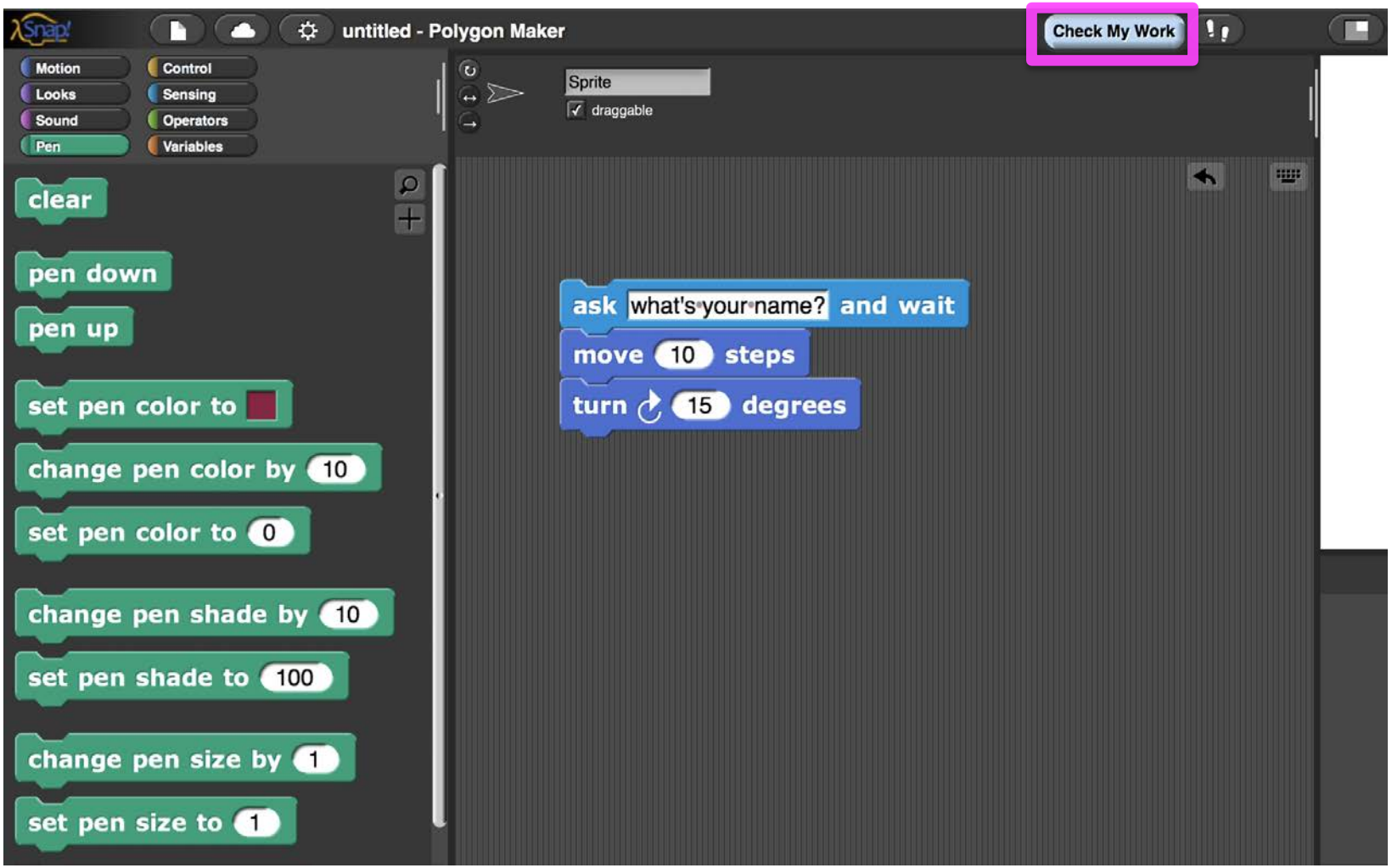
- Jill feels **stuck**.
- It is **Midnight** ..



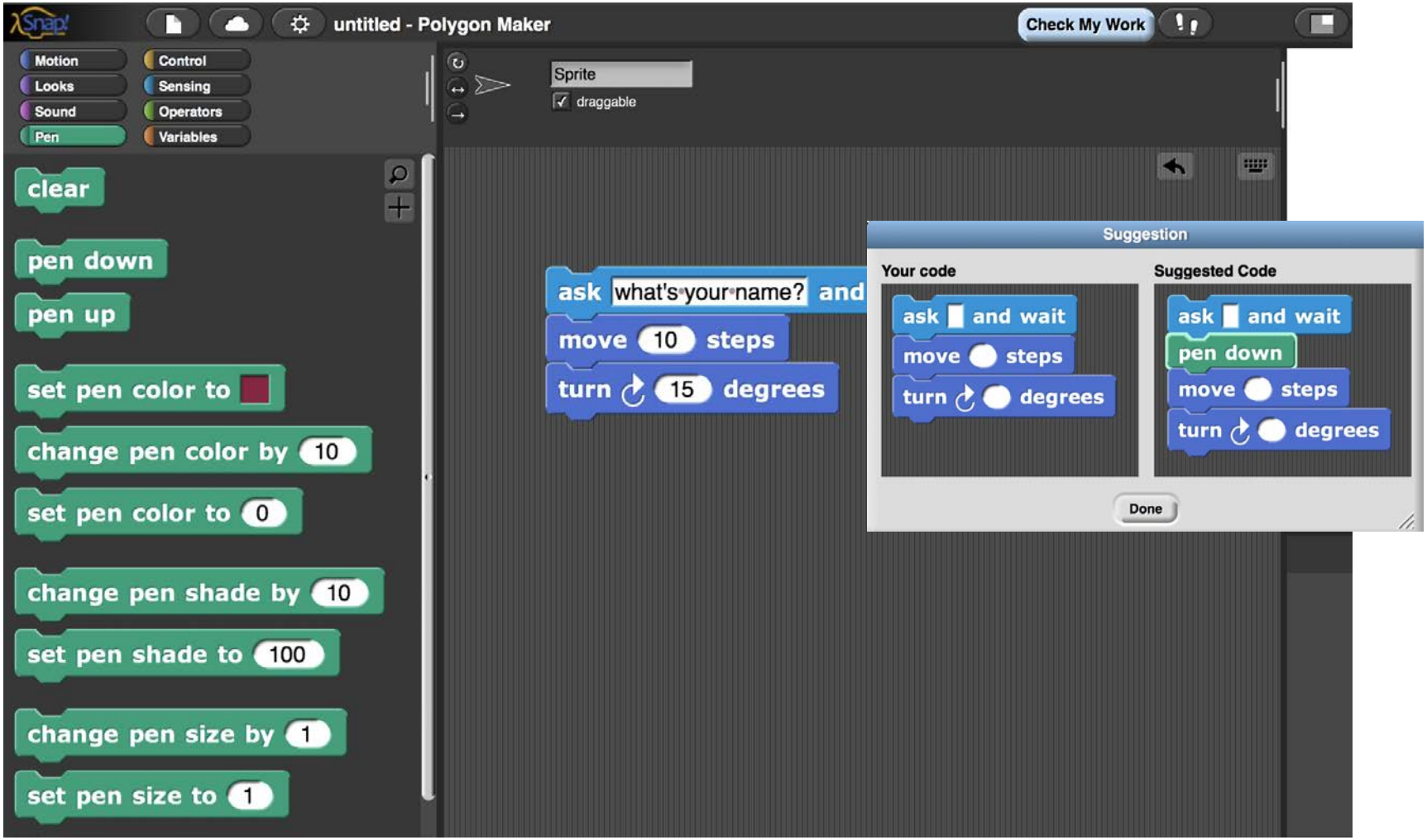
- One way to help Jill is to allow the programming environment to provide him with automated hints.

- Why automated hints?
  - Adaptive to students' code.
  - Can scale to new problems and contexts.
    - (Price at al., 2017, Rivers et al., 2017)
  - Can improve students' performance and learning.
    - (Corbett et al., 2001, Fossati et al., 2015)

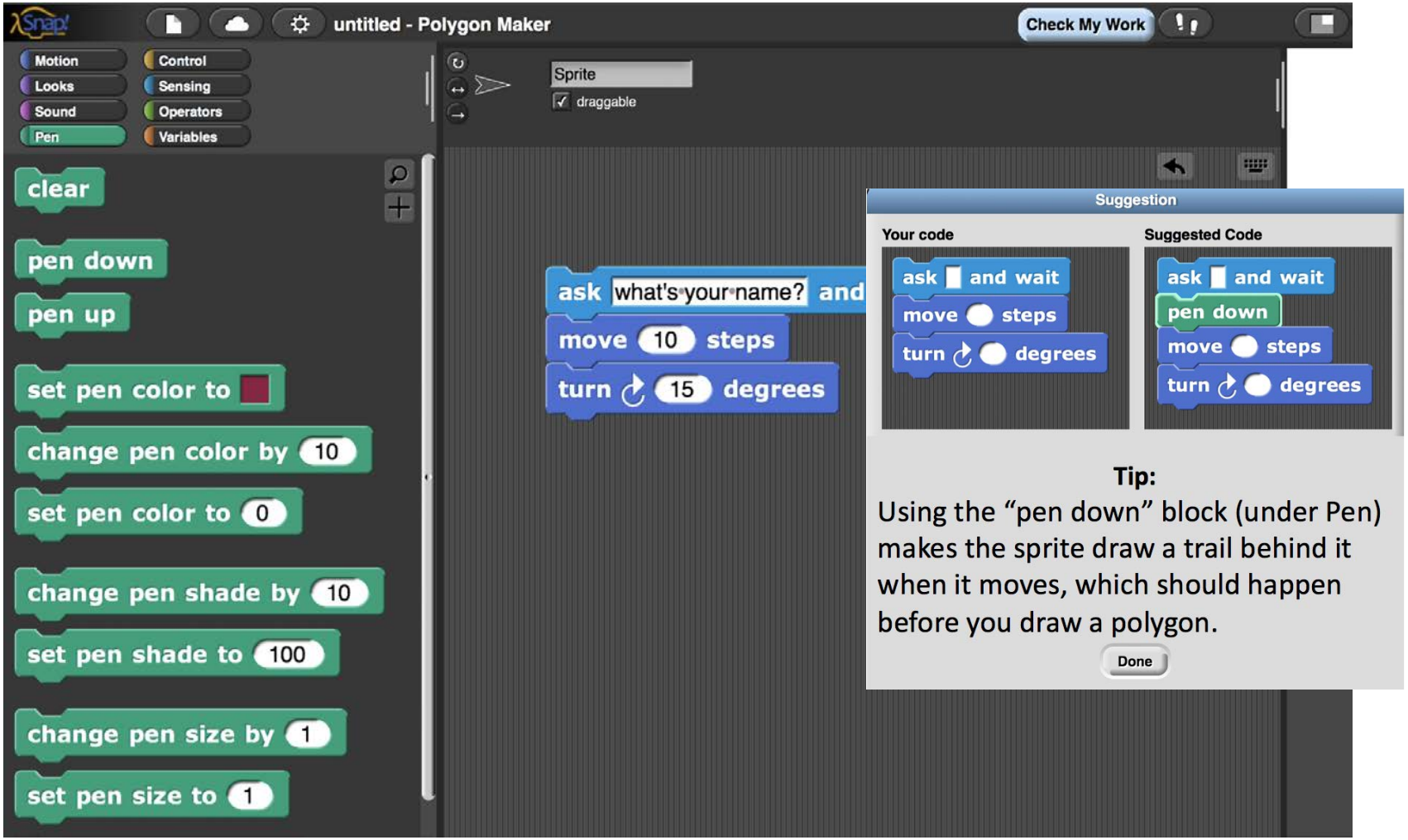
- Jill can ask for a hint from iSnap (Price et al., 2017)
  - But there are many design choices to consider….



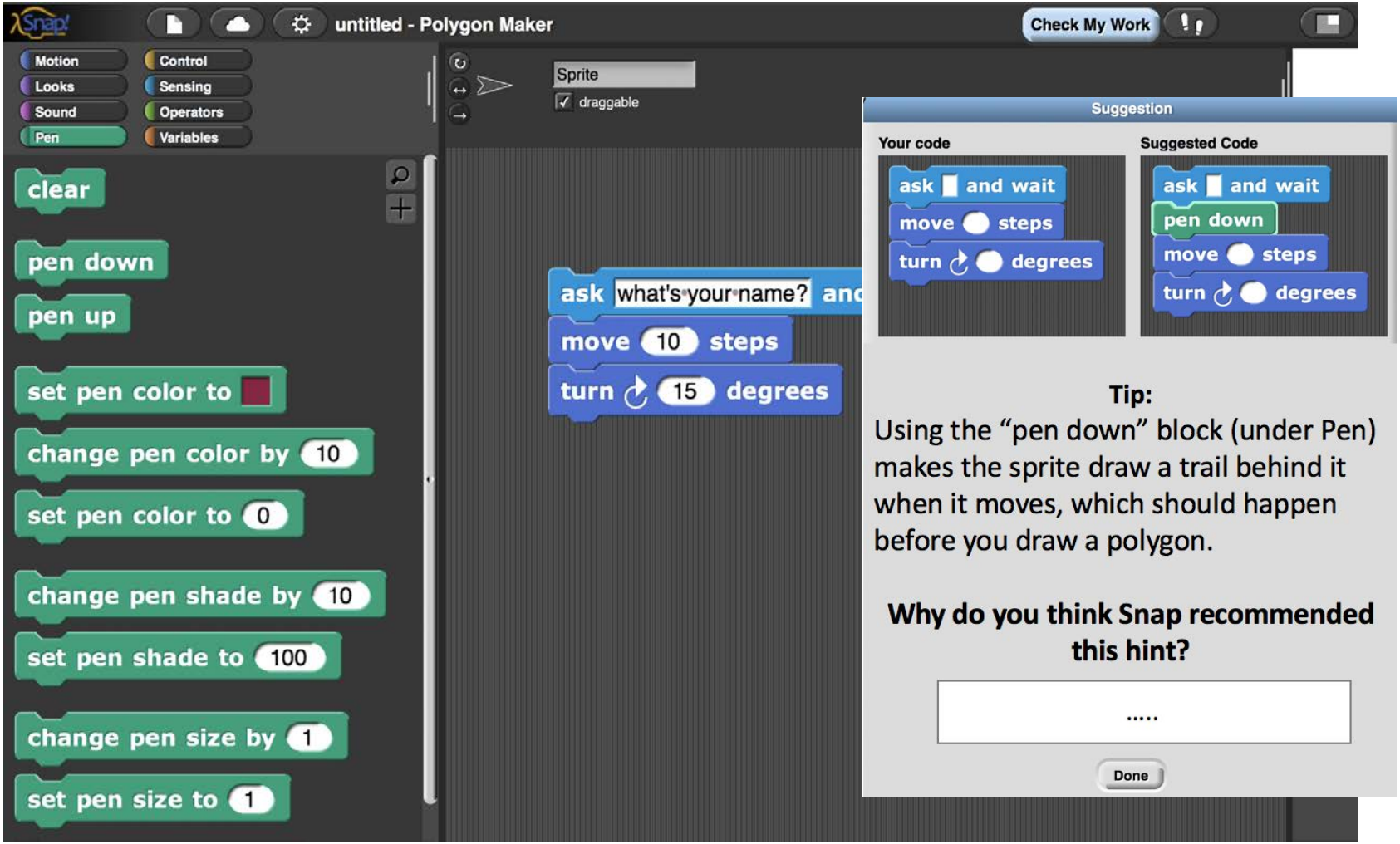
- Should the hint show Jill *only the next step to do*? (eg. Rivers et al., 2017, Watson et al., 2012)



- Should the hint give some *text explaining why and how* Jill needs to do this step? (e.g. Marwan et al., 2019)



- Should the hint ask Jill to *self-explain* the hint ? (e.g. Vihavainen et al., 2015)



Motivation

- While there is some evidence that programming hints can be helpful, there are many open questions:
  - How and when is each type of hint useful?
  - Do automated hints only get students 'unstuck'? Or can they lead to learning as well?
  - Automated hints only show *what* to do – is this sufficient, or do we need human-authored explanations?
  - What are students' perceptions on each hint design?

HINTS

Primary Contributions

- Additional features to next-step *code* hints: *textual explanations*, and *self-explanation prompts*.

- Study 1:
  - Students' perspectives on the value of code hints with different features.

- Study 2:
  - Impact of code hints with additional features on students' behavior (e.g. performance, and learning).

Overview

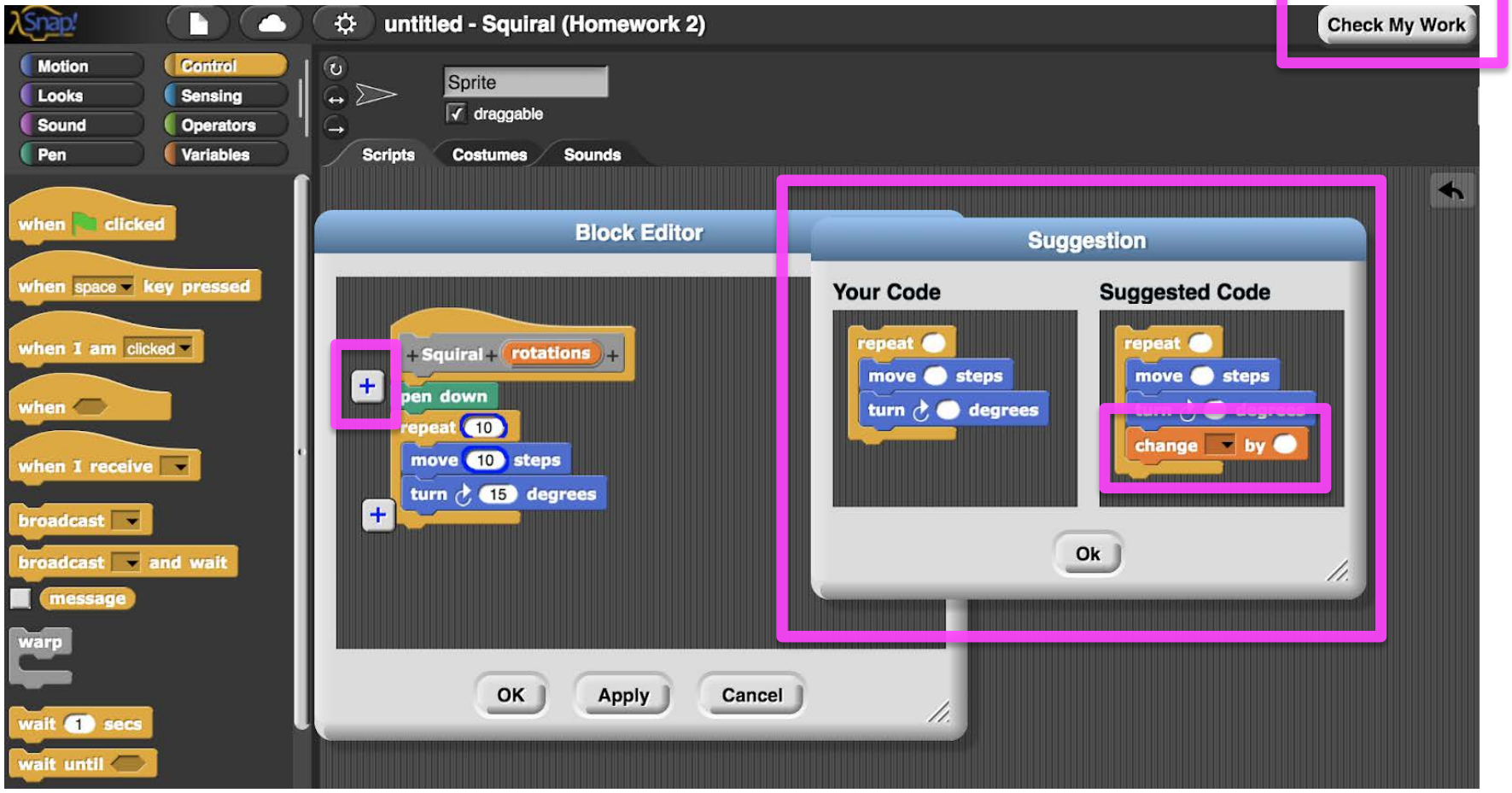
- Hints Design
- Study 1
- Study 2
- Discussion
- Future Work

How do we design effective hints for programming?

DESIGN OF HINTS

Hint Design: Code Hints

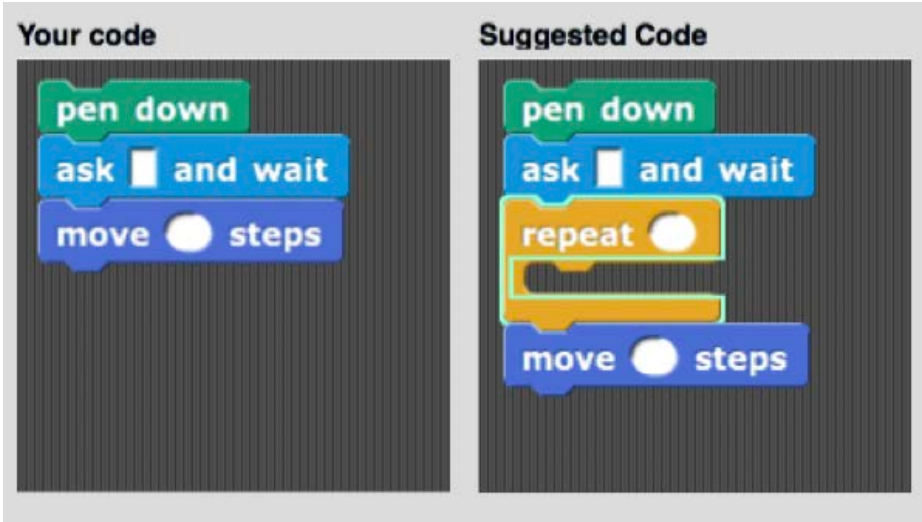
iSnap already provides ***Code hints*** that suggest an **edit** the student can make to get close to a correct solution.



Limitation #1: Lack of Explanations

Code hints say **what to do**, but they do not say **why**.

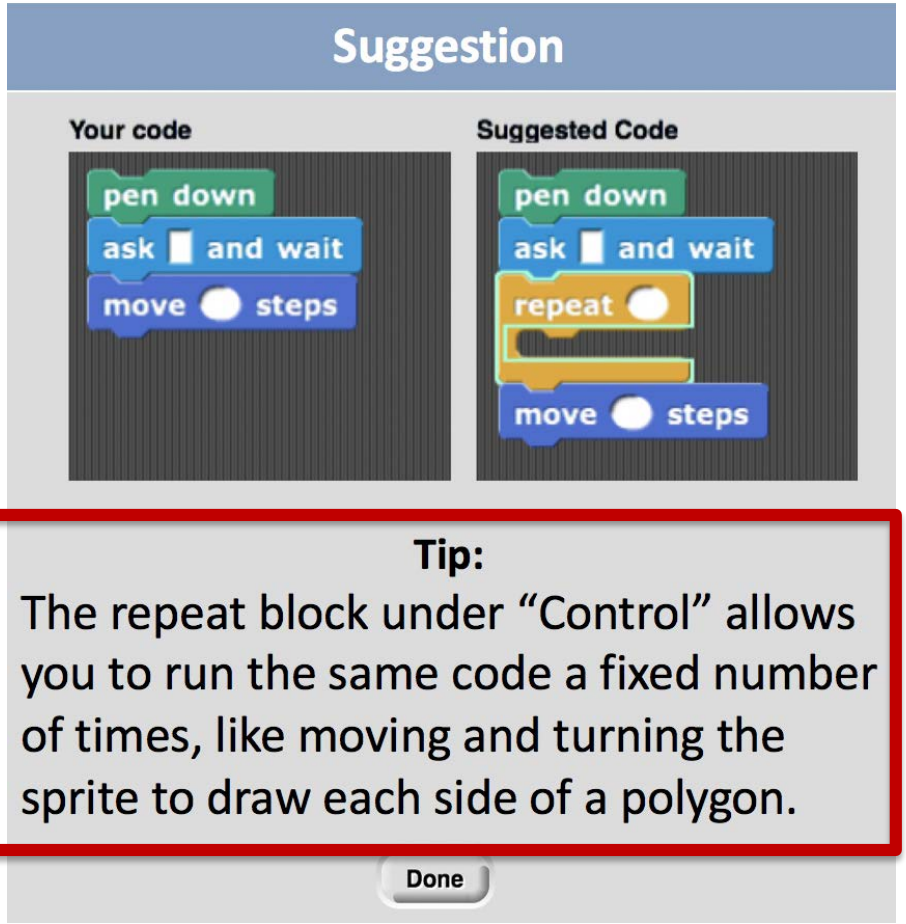
- This makes hints difficult to interpret (Price et al., 2017, Gusukuma et al., 2018).



Solution: Add Textual Explanations

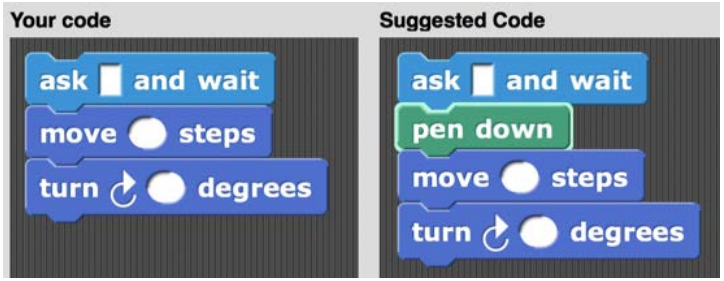
- To address this, in our prior work, we studied adding textual explanations to code hints (Marwan et al., 2019).

- **Results:**
  - Learners rate hints as more useful, and interpretable, compared to code hints only.
  - However, we did not find evidence that these hints improve learners' performance



Limitation #2: Bottom-out Hints

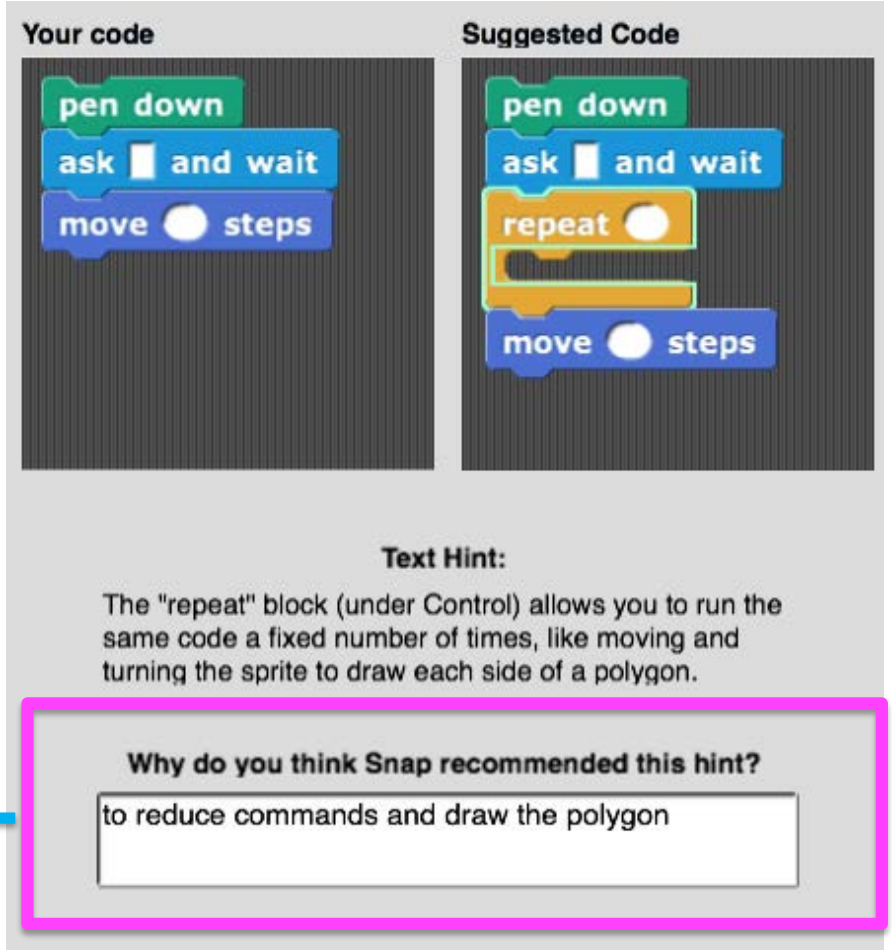
Code hints are "bottom-out" hints that give away part of the solution



- Leads to learning ***only*** when students spontaneously self-explain the hint (Aleven et al., 2016, Shih et al., 2008).
- Self-explanations of examples can benefit learning (Williams et al., 2016, McNamara et al., 2017).
  - However, they may frustrate learners (Shin et al., 2018).
- Fewer studies have explored self-explanation prompts in programming (Vihavainen et al., 2015, Vieira et al., 2017).

Solution: Self-Explanation Prompts

Explore: the effect of adding self-explanations to hints in iSnap.



Self-Explanation Prompt:

Require students to reason about the information they have received.

What are students' perceptions on each hint design?

STUDY 1

Study 1

Goal:

- Understand ***students' subjective perceptions*** of code hints, textual explanations and self-explanation prompts
  - Specifically: ***when*** and ***how*** they are helpful, and ***how they can be improved***.

Study 1

Population:

- 10 Undergraduate students, who have attested to have no prior programming experience.
    - Limitation: all *males*; ages (18-20)

Procedure:

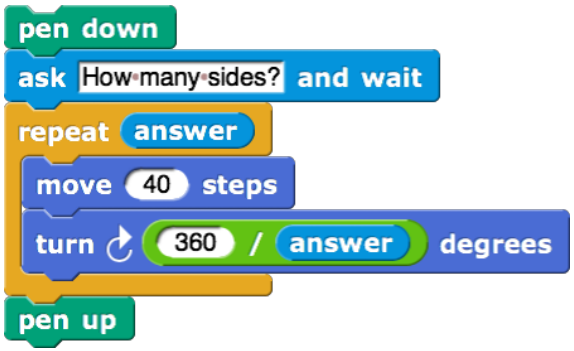
- 1-on-1 user-study.

Step 1	iSnap tutorial	5-10 min
Step 2	Task 1	15-20 min
Step 3	Interview 1	5-10 min
Step 4	Task 2	15-20 min
Step 5	Interview 2	8-12 min

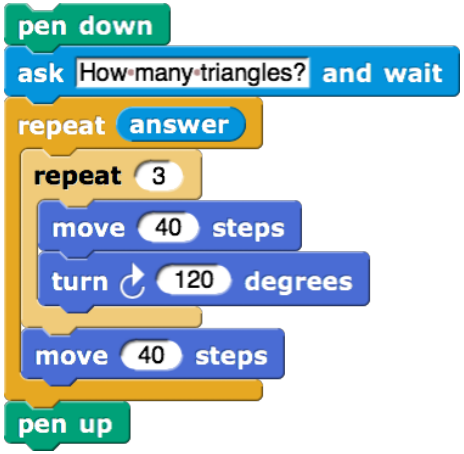
HINTS

Programming Tasks

- Draw a regular polygon with any number of sides.



- Draw a series of triangles.

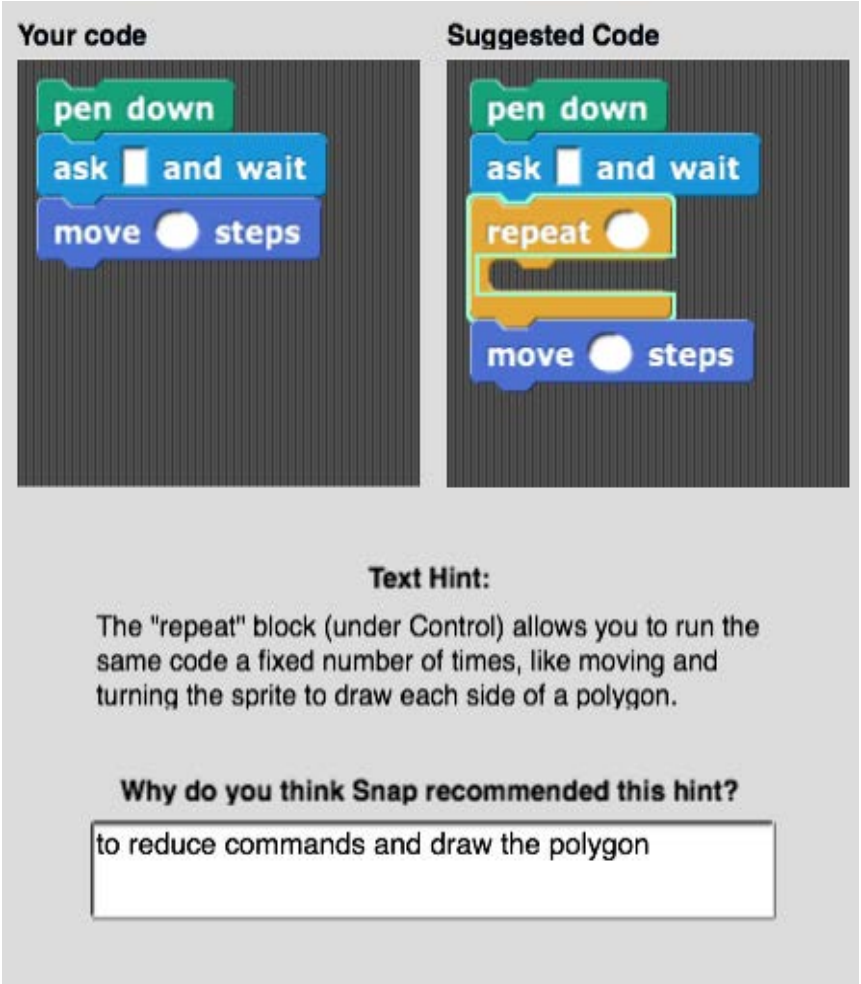


Study 1

Procedure:

For both tasks, students received all types of hints randomly:

All Conditions: Code Hints



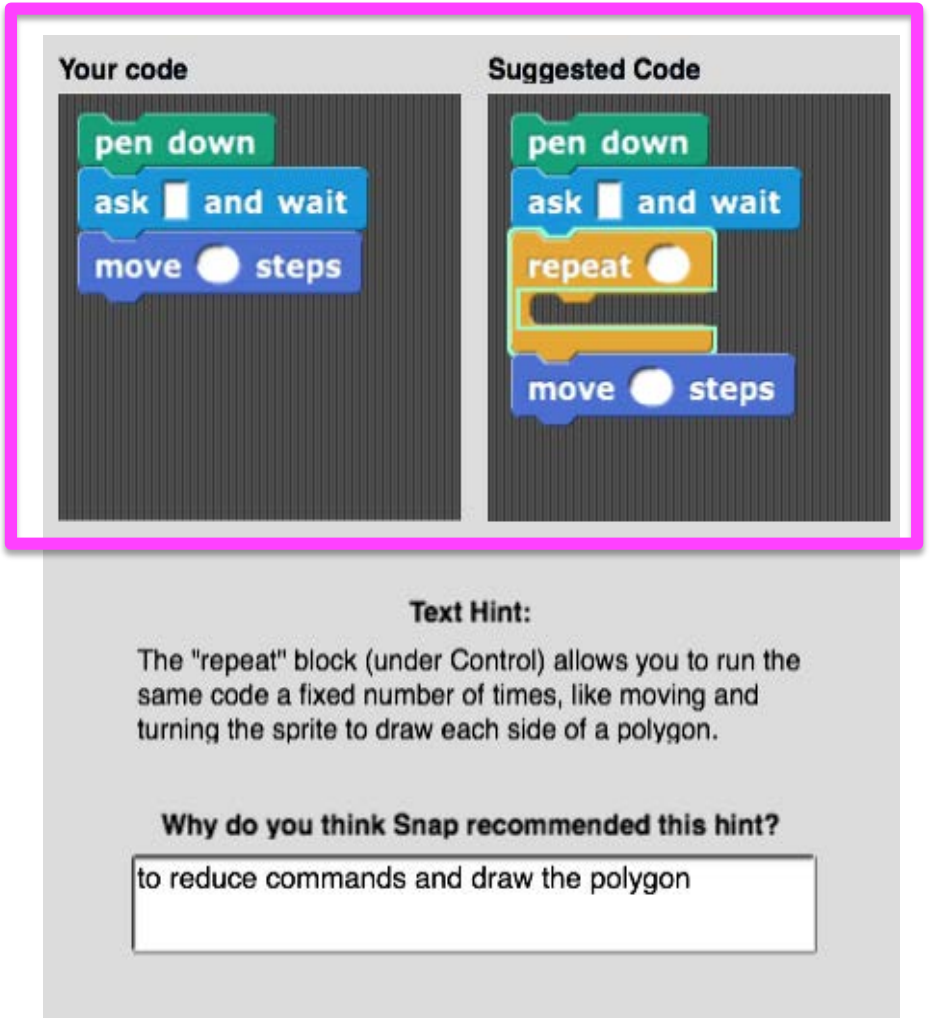
Study 1

Procedure:

For both tasks, students received all types of hints randomly:

All Conditions: Code Hints

[Only Code Hints]	



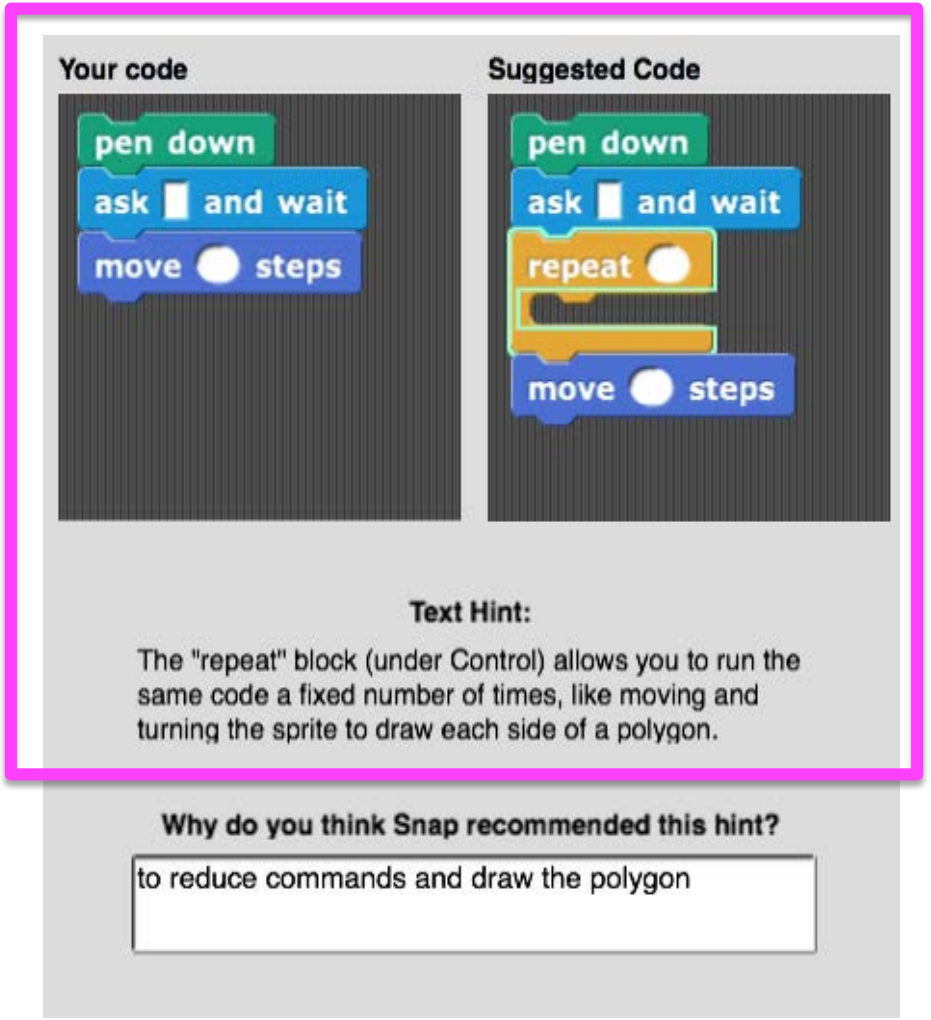
Study 1

Procedure:

For both tasks, students received all types of hints randomly:

All Conditions: Code Hints

[Only Code Hints]	+ Text Expl.



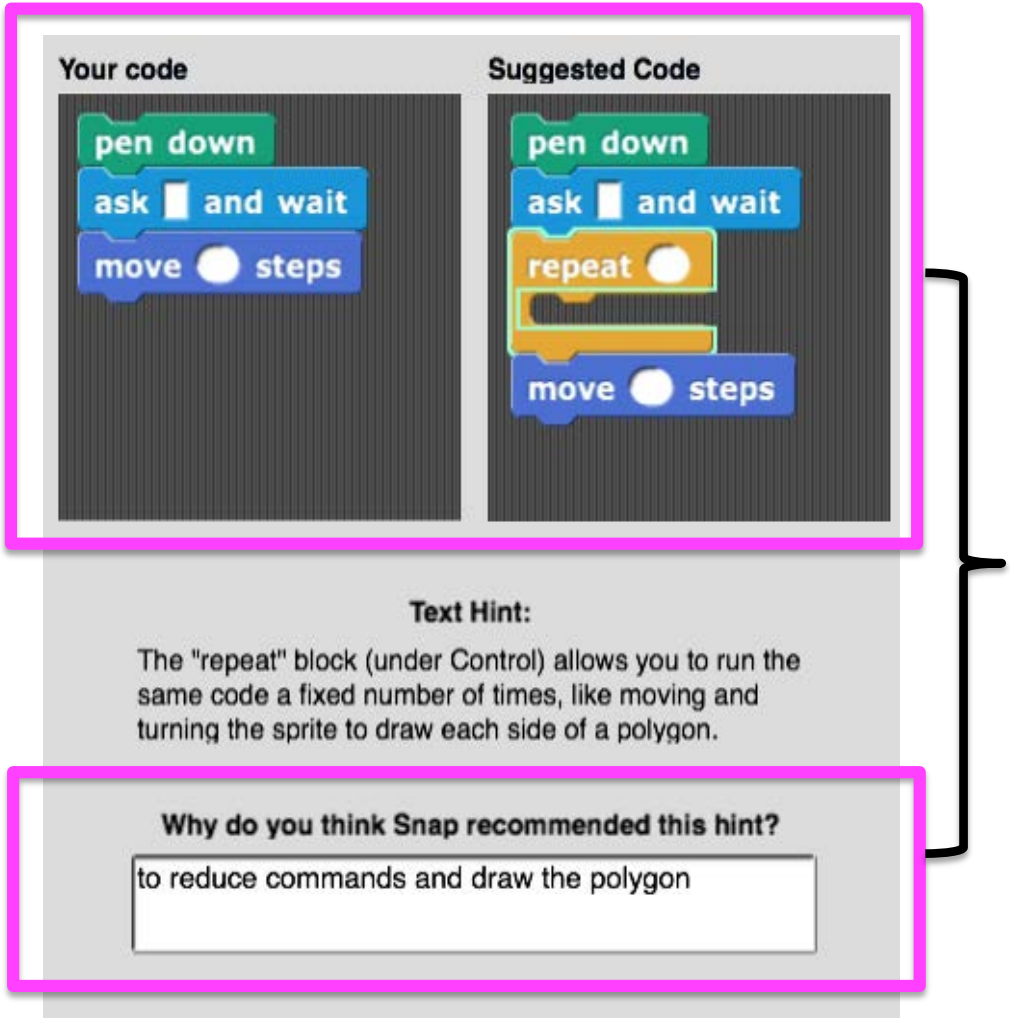
Study 1

Procedure:

For both tasks, students received all types of hints randomly:

All Conditions: Code Hints

[Only Code Hints]	+ Text Expl.
+ SE Prompts	



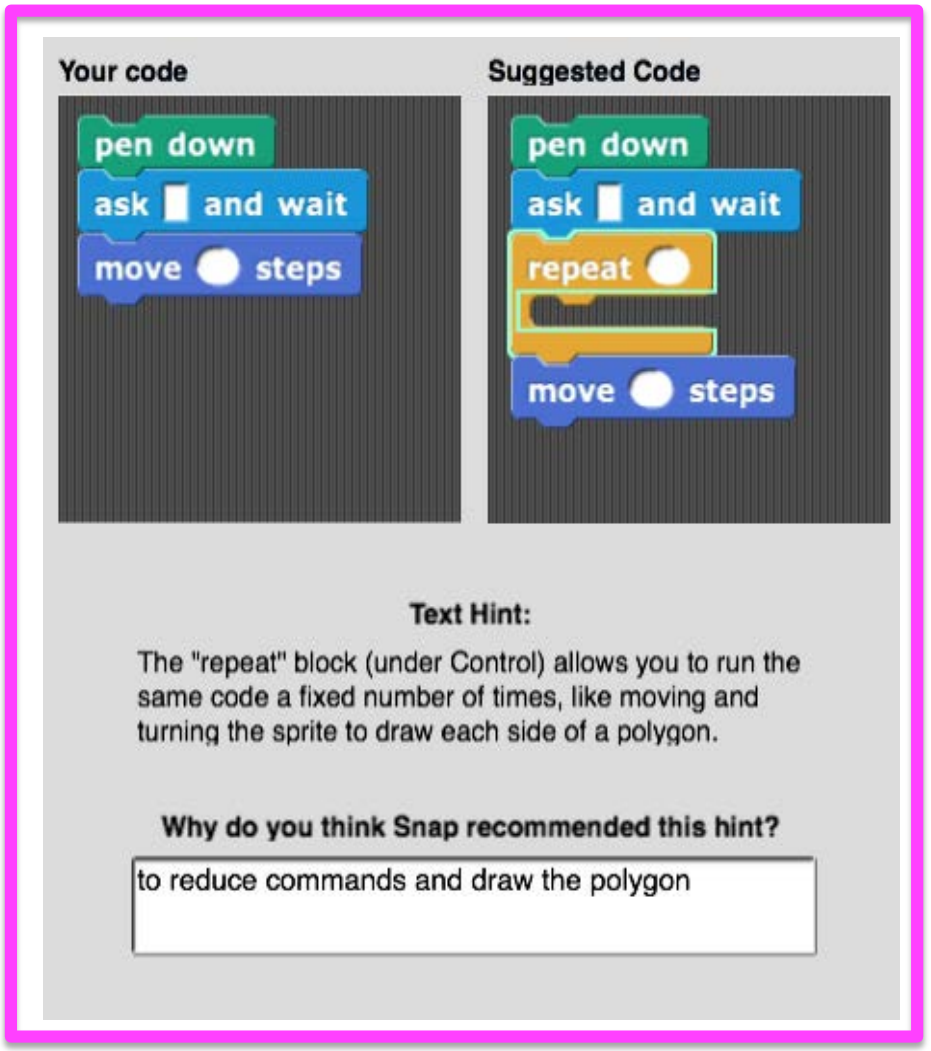
Study 1

Procedure:

For both tasks, students received all types of hints randomly:

All Conditions: Code Hints

[Only Code Hints]	+ Text Expl.
+ SE Prompts	+ Text Expl. + SE Prompts



Study 1

Data:

- Complete traces of students' work.
- Audio-recordings of students' interviews

Qualitative Analysis

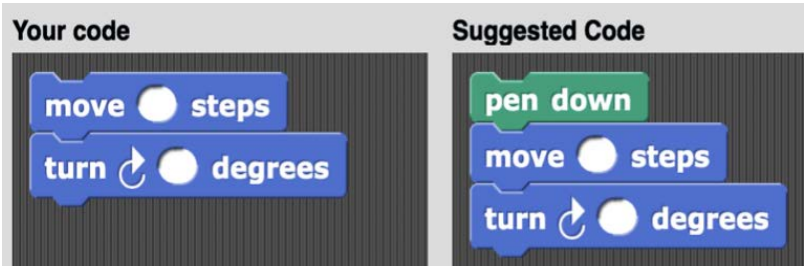
- All 10 students responses were analyzed by:
  - Identifying and grouping both **positive** and **negative** themes that emerged for each type of hint and how they can be improved.

Study 1

HINTS

Code hints:

– Helped students to see a clear next action they could take.



P10

"it showed you your code next to what you should do"

➢ Specifically useful for students who are using iSnap for the first time.

P6

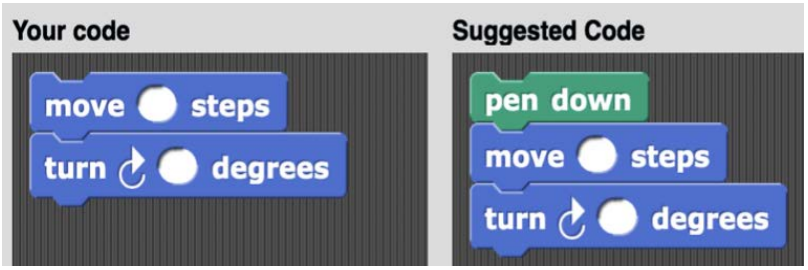
"it gives you something that you had not thought about."

Study 1

HINTS

Code hints:

- *However*, Code Hints only said what to do, but not why



P3

"it just told me what to do but I did not know what the problem is or how can I fix it up"

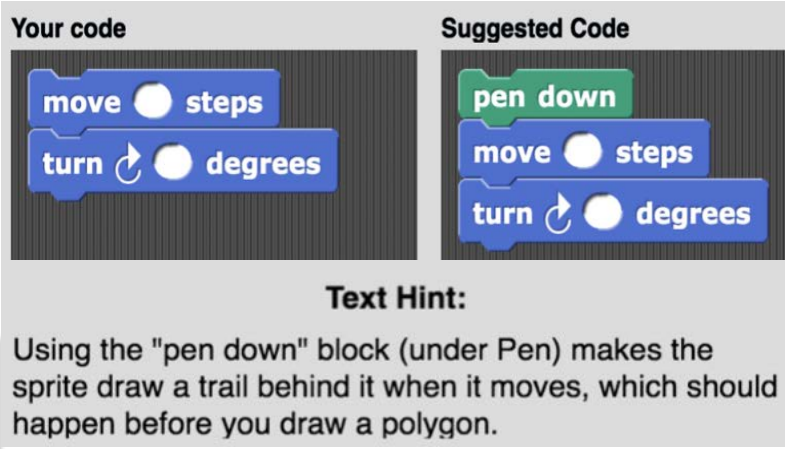
P9

"code hint itself cannot provide enough information"

Study 1

Code hints with Textual Explanations:

- Gave useful but different information from a code hint.



P6

"[the code hint] shows which block to use and the text gives an idea of what to use it for."

- *No downside for the student* (easy enough to ignore)

P9

"[Adding text hints to code hints] can not be not helpful."

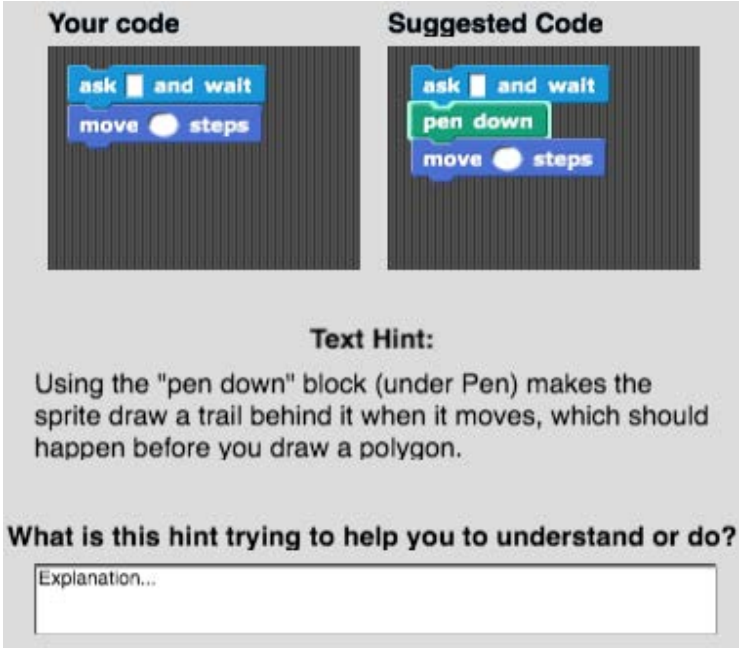
Study 1

Self Explanation Prompts with Hints:

- Help students stop and think more deeply about the hint.

P8

"it made me think and take a step back about the whole process."



- *However*, they can be frustrating and confusing.

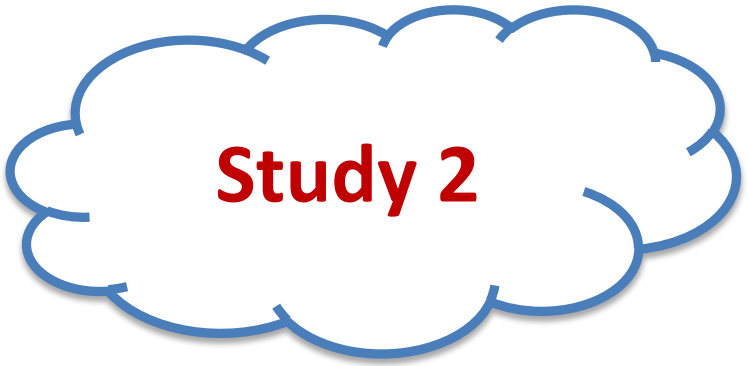
P5

"it is not giving me anything back, it is just asking me if I understood it."

Study 1

Our results suggested that:

- Students see the benefits in all three types of hint support, which offer complementary benefits.
- *However*, some students did find self-explanation prompts to be confusing or irritating.
- Therefore, it is important to investigate how they impact students' outcomes.



What is the effect of hints on learners' performance and learning?

STUDY 2

Study 2

Goal:

- Investigate the effect of hints on *performance* and *learning* in a *larger-scale study*.

Research Questions:

What is the effect of hints *with and without* self-explanation prompts on:

1. learners' ***performance***?
2. their ***learning*** (performance on future tasks without hints)?
3. their ***hint usage*** during programming?

Study 2

Population:

- 201 total crowd workers through Amazon's Mechanical Turk (MTurk) platform.
  - Have no prior programming experience.

An effective form of conducting large-scale user studies in lieu of using university participants (Behrend et al., 2011, and Kittur et al., 2008)

  - Demographically similar in age and education level (84.5% B.S. degree).

Study 2

Procedure:

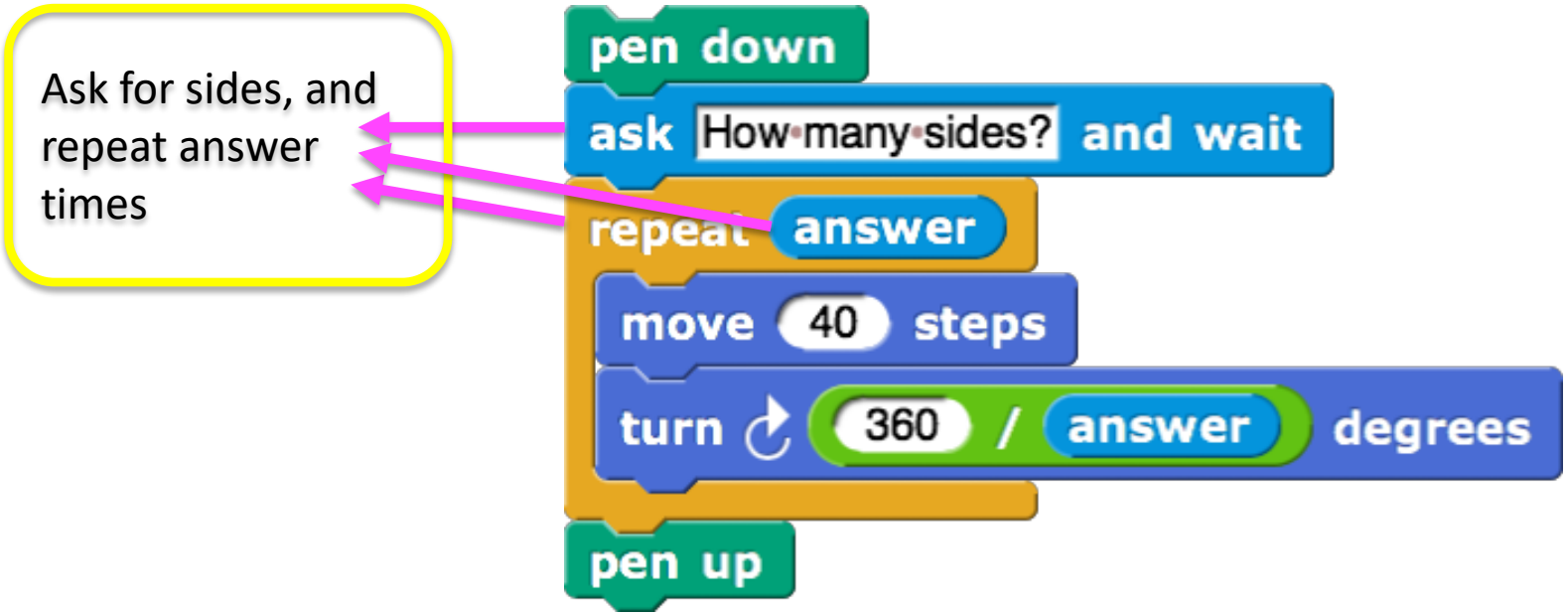
- Similar to study 1 (iSnap tutorial, task 1, task 2), **except**:

1- Each learner is assigned to one condition: • **CT:** Code + text • **CTE:** Code + Text + Prompt • **Control:** No Hint	2- Task 2 was used as a post-test: • No hints were given to all groups. • Used to assess learning
3- Study 2 was online study, *without interviews*	4- Both Tasks were only for 15 min.

Study 2

Measures:

- Performance:
  - Each task is divided into 4 objectives



Study 2

Measures:

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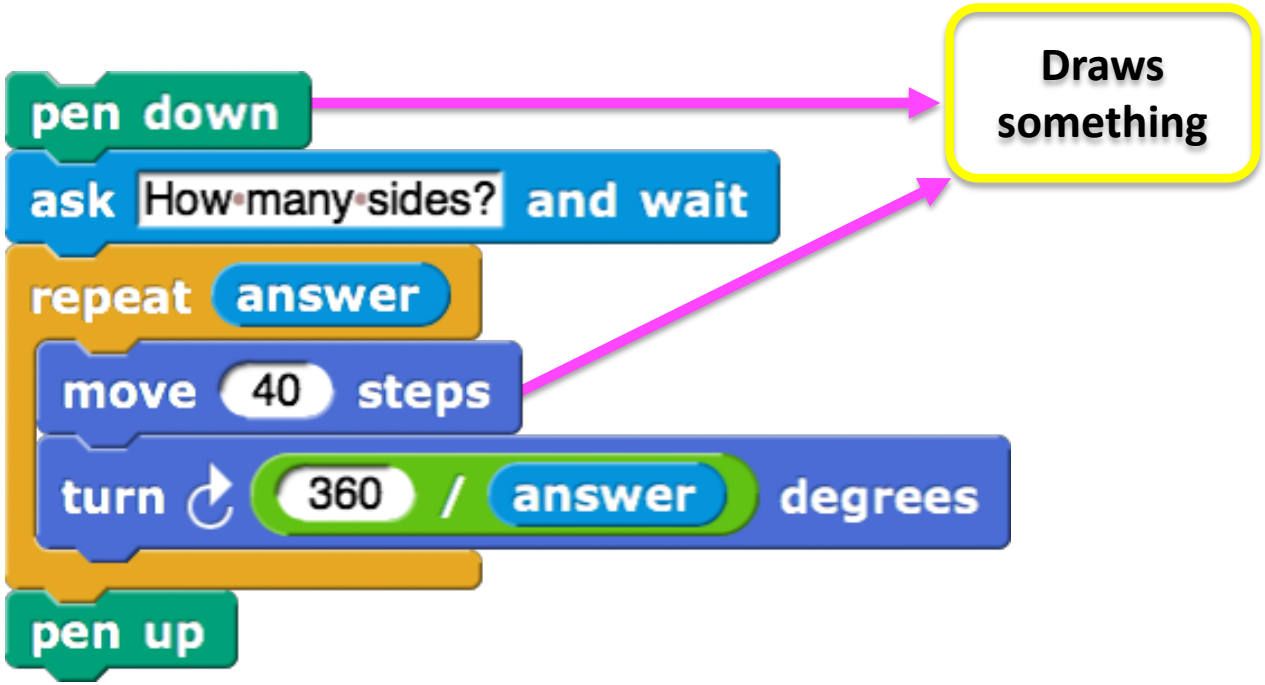


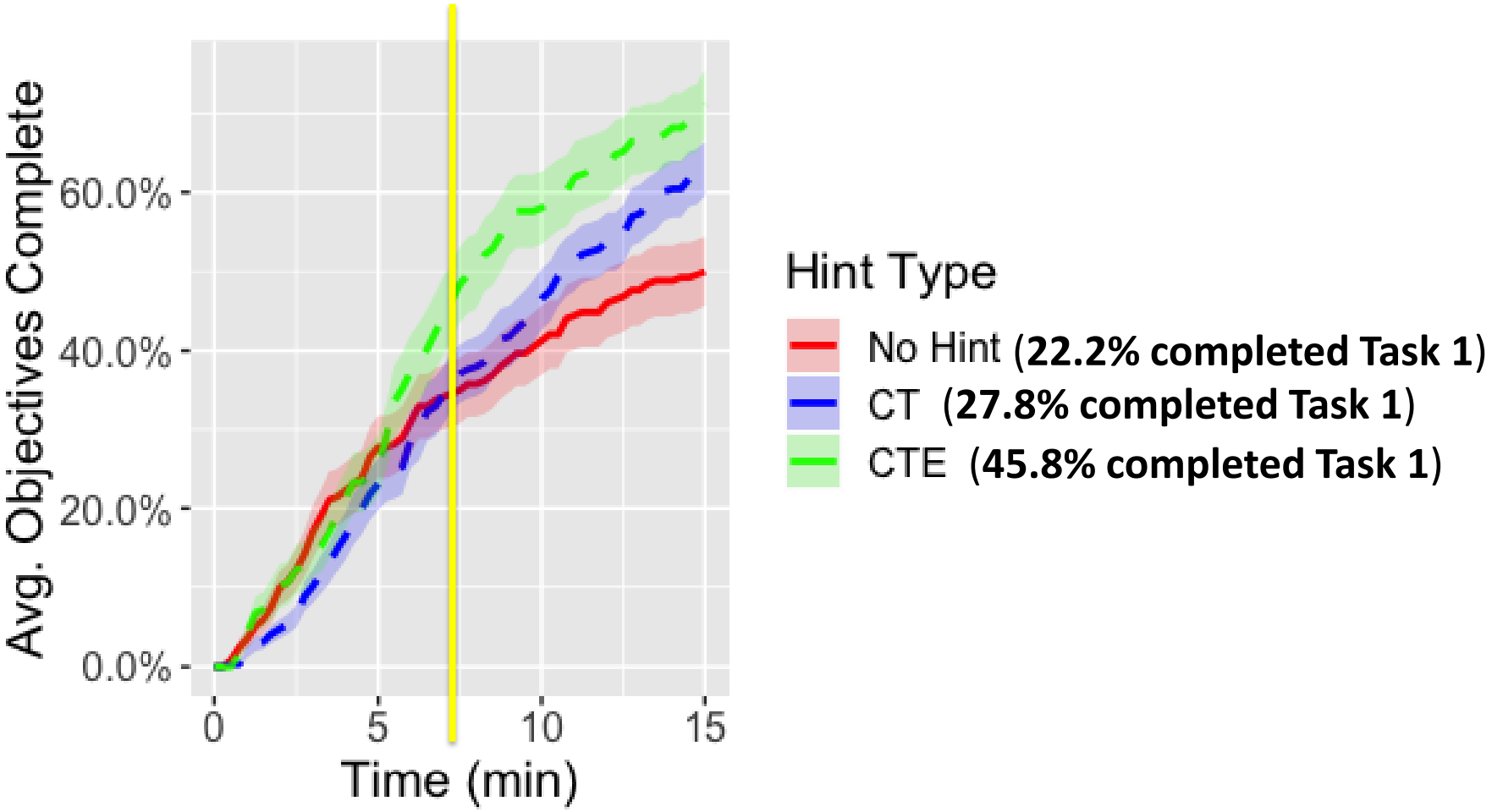
Study 2

Measures:

- Performance:
  - developed an automatic grader to determine the number of objectives completed by each learner.
  - analyzed time taken to complete each objective.

Study 2

RQ1: What is the impact of hints on learners' ***performance***?



Study 2

RQ1: What is the impact of hints on learners' ***performance***?

	Control	CT	CTE
Mean	2	2.53	2.8
SD	1.40	1.24	1.31
***P*-value**	**0.001**		

Kruskal-Wallis test

Both conditions with code hints *completed significantly more objectives* than the control condition.

- Dunn's test with Benjamini-Hochberg correction for multiple comparisons:
  - Control group and CT learners (***p* = 0.045**)
  - Control group and CTE learners (***p* = 0.001**)
  - CT and CTE learners ($p = 0.104$).

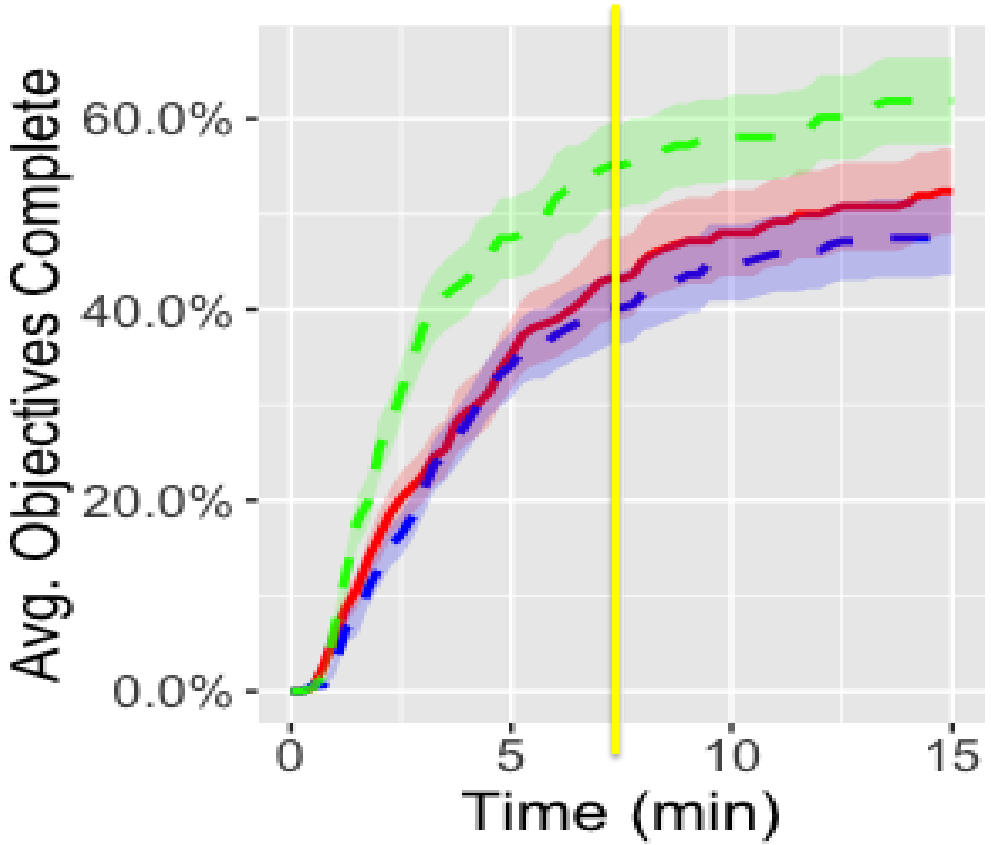
Study 2

Measures:

- Learning:
  - Task 2 served as our measure of learning
    - *No hints on this task*.
  - Consists of 4 objectives.
    - First two objectives *were identical* to the first two objectives in Task 1
      - Measure how well participants *learned to repeat these steps in a new context*.
    - Last two objectives *were different*
      - measured learners' ability to *apply the same programming constructs in a new way* (e.g. *use of nested loops*).

Study 2

RQ2: What is the impact of hints on learners' ***learning***?



Hint Type

- No Hint **26.9% completed Task 2**
- CT **25.3% completed Task 2**
- CTE **40.6% completed Task 2**

Kruskal-Wallis test showed that this difference was not significant (p = 0.06)

Study 2

RQ2: What is the impact of hints on learners' ***learning***?

- Performance on the first two objectives on Task 2 (*isomorphic to Task 1*):
  - A Kruskal-Wallis test shows a significant difference across groups (***p* = 0.013**).
  - A post-hoc Dunn's test with Benjamini-Hochberg correction for multiple comparisons:
    - CTE learners and the Control group (***p* = 0.01**)
    - CT learners and the Control group (*p* = 0.59).
    - CTE learners and CT learners (***p* = 0.028**)

Study 2

RQ3: What is the impact of hints on learners' ***Hints Request Rate***, and ***Follow rate*** in Task 1?

Study 2

RQ3: What is the impact of hints on learners' ***Hints Request Rate***, and ***Follow rate*** in Task 1?

1. **Hints Request Rate:** *Average number of hints requested by each learner.*
   1. *CT* ***requested significantly more*** *hints than CTE.*

	CT	CTE
Median	6	4
***P*-value**	**0.003**	

2. **Hints Follow Rate:** *The average number of requested hints that have been followed by each learner.*
   1. *CTE* ***followed significantly more*** *hints than CT.*

	CT	CTE
Median	0.57	0.71
***P*-value**	**0.03**	

Implications and relation to prior work

DISCUSSION

Summary of the Results

Code hints with or without self-explanation improve learners' immediate programming performance.

- Aleven et al.: next-step hints' primary role is to help students when they get stuck (2016).
  - From *Study 1*, students appreciated the hints':
    "it just puts me in the right direction". [P2]

  - From *Study 2*:
    - Learners in both ***CT*** and ***CTE*** conditions completed significantly more objectives than the control group.

HINTS

Code hints only improved learning when accompanied by self-explanation prompts.

- Rivers' evaluation of next-step hints did not find a learning effect (2017).
- In the KLI framework, Koedinger et al., argued that "sense making" is necessary for learning from hints (2012).

- From *Study 1*, 70% of participants appreciated self-explanation prompts
  "*[it helps] to interpret what... the picture [hint] mean[s]*" [P2].

- From *Study 2*:
  - ***CT*** learners ***performed no better*** than the control condition.
  - ***CTE*** learners ***performed significantly better***, only ***on isomorphic objectives*** with Task 1.

HINTS

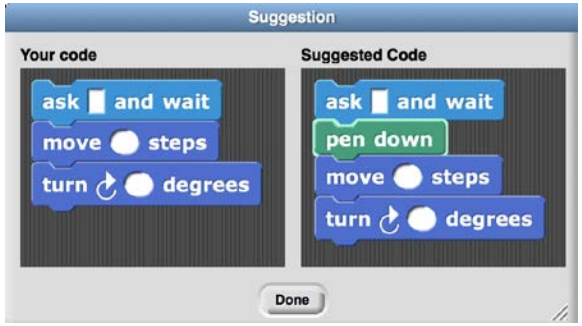
Self-explanation prompts changed the way that students interacted with code hints.

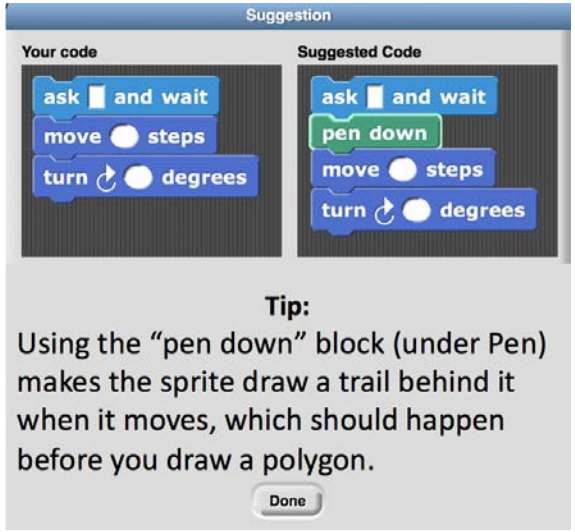
- Vieira et al., argue that adding self-explanation to worked examples increased students' engagement and awareness of the worked-example (2017).
  - From *study 1*, most participants noted that self-explanation prompts caused them to:
    - ***" think and take a step back about the whole process"*** [P6].
  - From *study 2*:
    - Learners in the ***CTE*** condition:
      - Spent *more time viewing each hint* than CT learners, *requested fewer hints*, but were *more likely to follow them*.

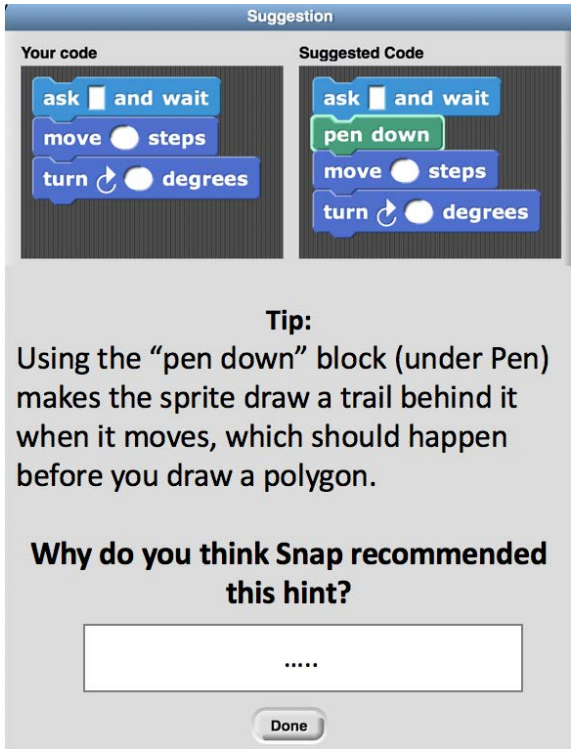
CONCLUSION & FUTURE WORK

Conclusion

Code hints can improve performance and learning, *but depending on how we present them*.



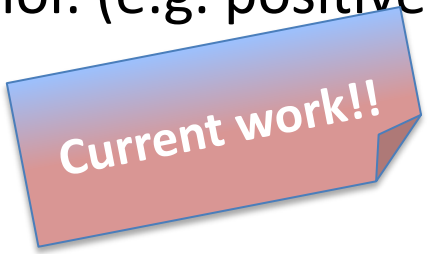




Future Work

- Investigate whether our results would generalize to a classroom context with more complicated programming tasks.

- Explore other forms of hints on students' behavior. (e.g. positive feedback).



- How textual explanations can be reused across several programming exercises.

Thank You!!
Questions?

Samiha Marwan
samarwan@ncsu.edu

HINTS

Dr. Joseph Williams
williams@cs.toronto.edu

The Intelligent Adaptive Interventions lab

Dr. Thomas Price
twprice@ncsu.edu

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