Debugging games

A new approach to computing education

Andrew J. Ko

Debugging is one of the most difficult parts of software development

Developers must master…

- Reproduction
- Input minimization
- Tools for inspecting runtime behavior
- Strategies for localizing defects

Debugging is even more difficult for **novices**

In the classroom…

We (usually) don't teach them how to do it

We (usually) require them to do it alone

Novices inject a lot of defects

We require them to learn it while also learning algorithms, data structures, and programming languages

Debugging is even *more* difficult for **teen girls**

Many already believe they're not good at "computers", so they're less likely to persist when they encounter failures

Social experiences are key to engaging girls, but debugging be quite solitary

Goode,J., Estrella,R., & Margolis,J.(2006). Lost in translation: Gender and high school computer science. In J. M. Cohoon & W. Aspray (Eds.) Women and Information Technology Research on Underrepresentation, 89- 114.

If we were to teach debugging…

What would we teach?

How would we teach it?

How would we teach it in a way that better engages and teaches learners who lack self-efficacy, such as girls?

Existing learning tech teaches coding, not debugging

Creativity + tinkering

touchdevelop

Alice

SCRATCH

(and 100's ot others in the past 50 years)

All require learners to struggle through the errors they create

Tutorials

touchdevelop

KHAN ACADEMY

codecademy

Most provide little feedback about errors and no debugging guidance

Games

CODE HUNT

CODE COMBAT

Lightbot™

And dozens of other competitive coding games

All coding oriented, not debugging oriented

We've been exploring a new kind of learning technology we call a **debugging game**

Led by my Ph.D. student Michael Lee, and several others:

Margaret Burnett (Oregon State)

1 postdoc, 3 other Ph.D. students, and 12 undergraduates, and 2 high school students

Why a game?

91% of U.S. kids aged 2-17 play video games

Social games are particularly popular among teen girls in the U.S.

Teen girls particularly enjoy both cooperative and competitive puzzle and strategy games

NPD (2011). Kids & gaming 2011 report. NPD Group.

Ito, M., Baumer, S., Bittanti, M., boyd, d., Cody, R., Herr B., Horst, H.A., Lange, P.G., Mahendran, D., Martinez, K., Pascoe, C.J., Perkel, D., Robinson, L., Sims, C., and Tripp, L. (2009). Hanging Out, Messing Around, Geeking Out: Living and Learning with New Media. Cambridge: MIT Press.

Participatory design

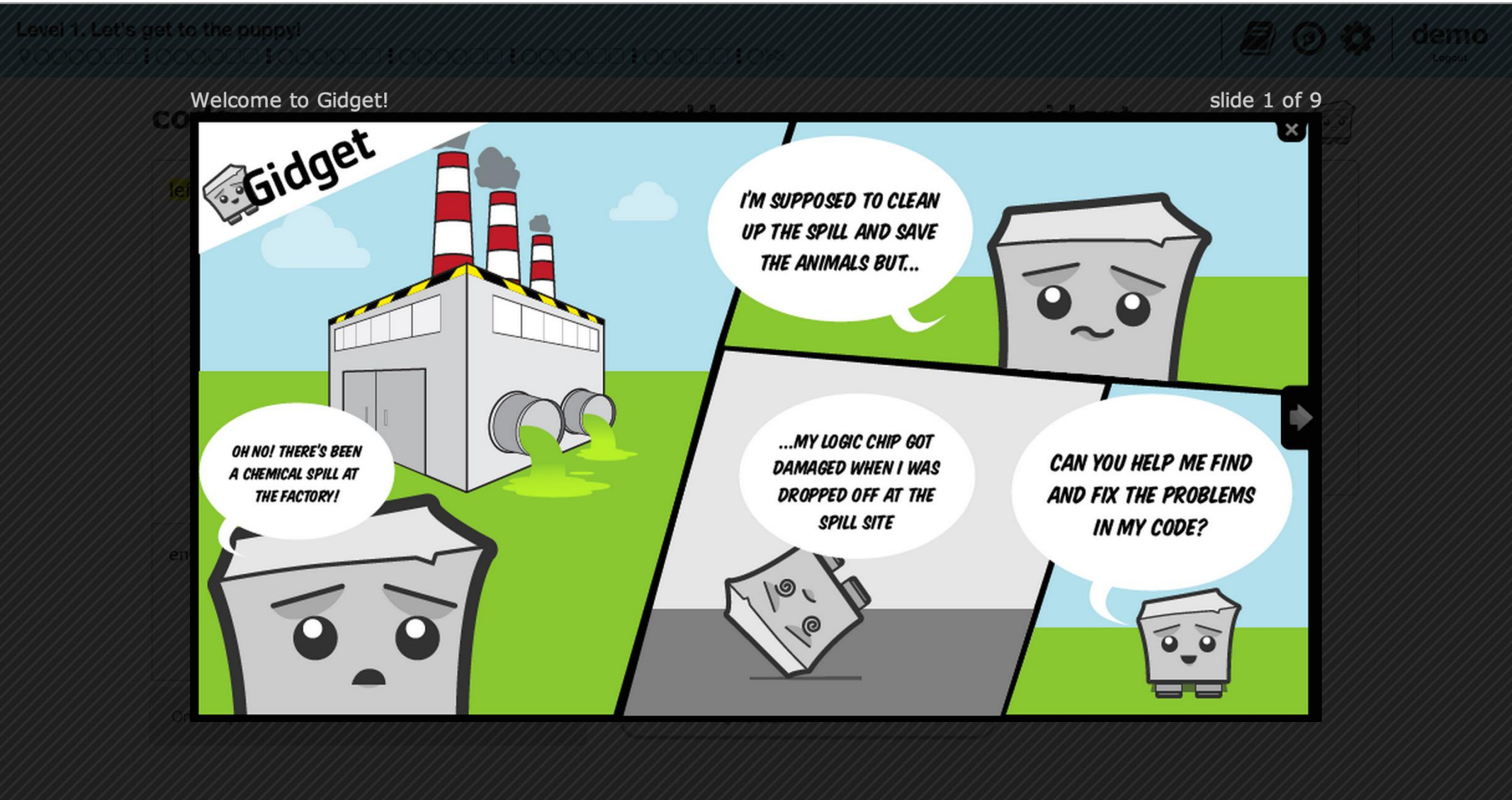
In 2011, Mike Lee and I gathered together a group of 10-12 year old girls and ideated possible game designs

We arrived at a design in which a player *helps* a computer that's struggling to write correct programs

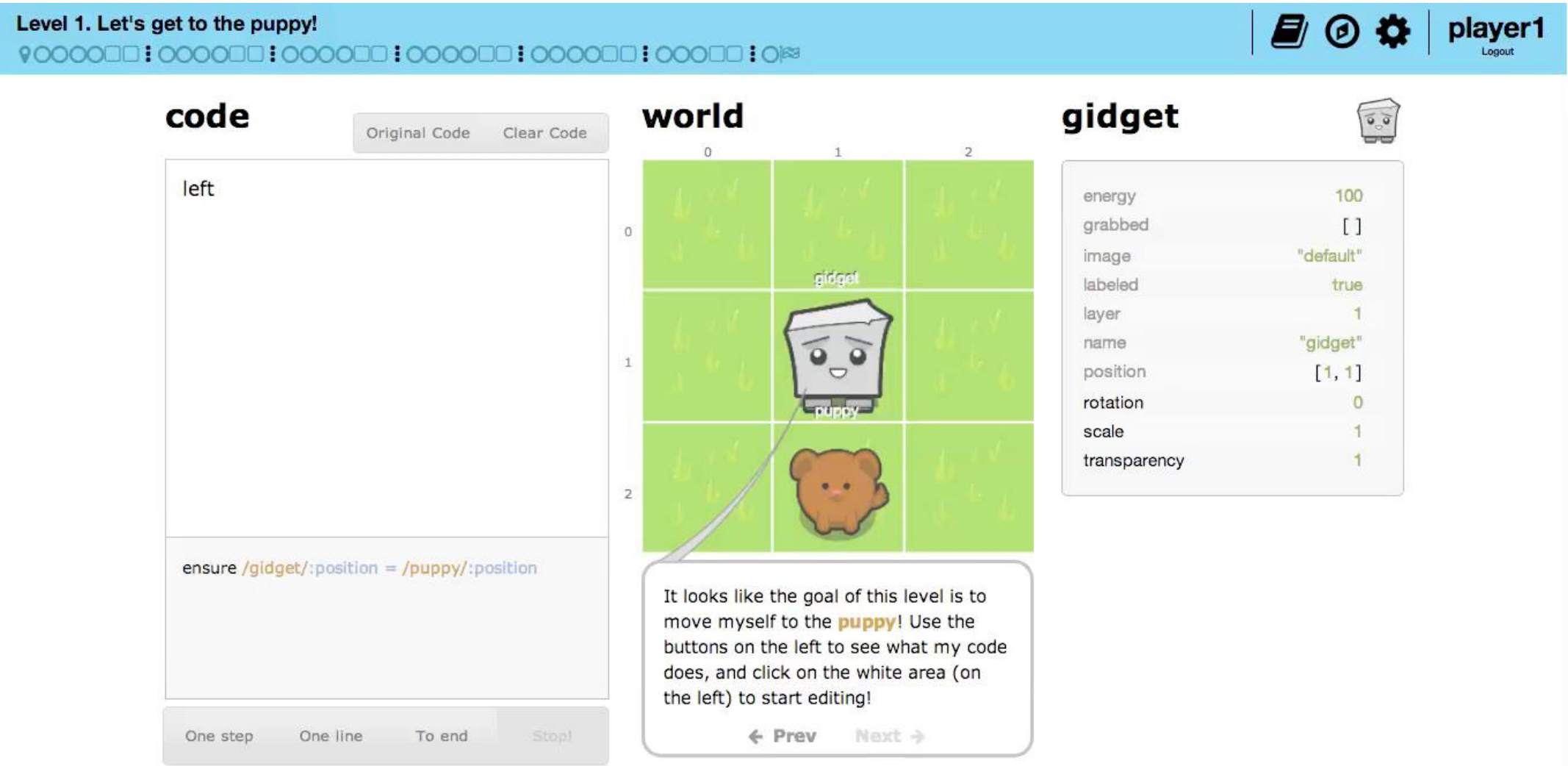
This way, debugging was about cooperating with a computer to solve a problem rather than fighting with it to make progress

Gidget is sent to clean up a chemical spill

He confides in the player that he every program he writes fails and he's not sure why



A full IDE in the browser



Each feature designed for learning

Level 20. Press the button, open the gate!

demo
Logout

code

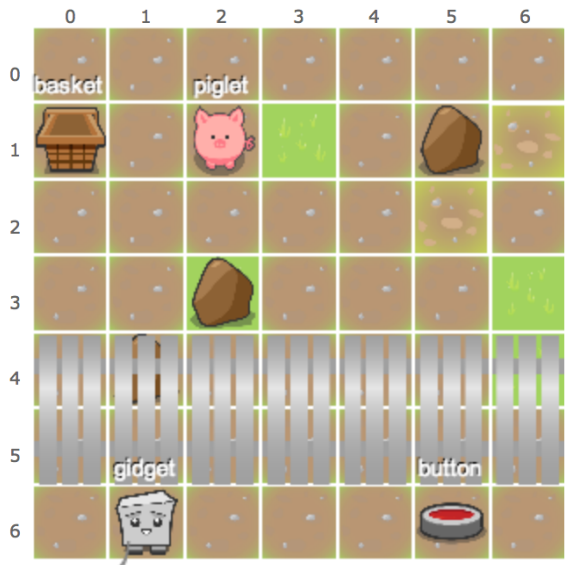
Original Code | Clear Code

```
goto /button/
say "Let's click the button to see its function
/button/:openFence()
function getPiglet()
   goto /piglet/
   set /piglet/:nickname to "wilbur"
   set /piglet/:age to 3
   grab /piglet/
getBird()
getThePiggy()
goto /basket/
```

```
ensure /piglet/:nickname = "babe"
ensure /piglet/:age = 3
ensure # /piglet/ on /basket/ = 1
```

One step | One line | To end | Stop!

world



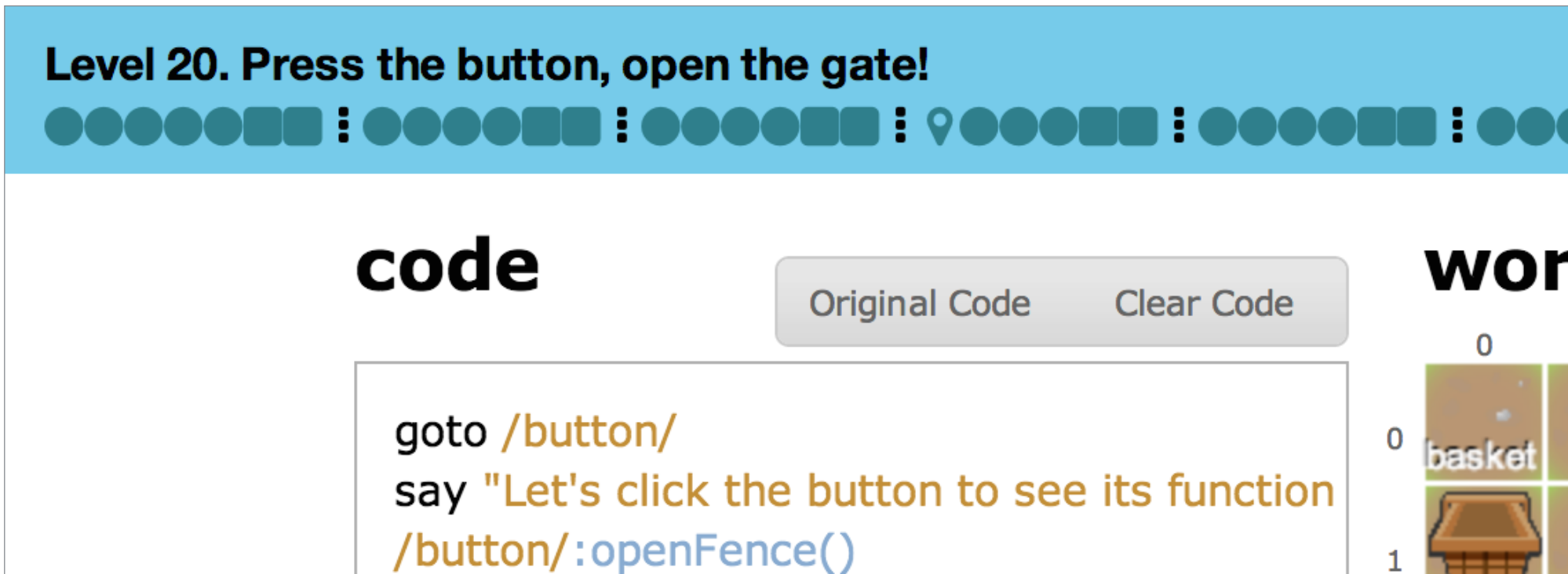
Let's figure out how to open the **gate** with the **button**, and give that **piglet** some new properties before we put it in the **basket**! Try running my code first to see what happens!

← Prev Next →

gidget

energy	100
grabbed	[ ]
image	"default"
labeled	true
layer	1
name	"gidget"
position	[6, 1]
rotation	0
scale	1
transparency	1

Every level is a defective program that the player must repair



Programs control Gidget the robot

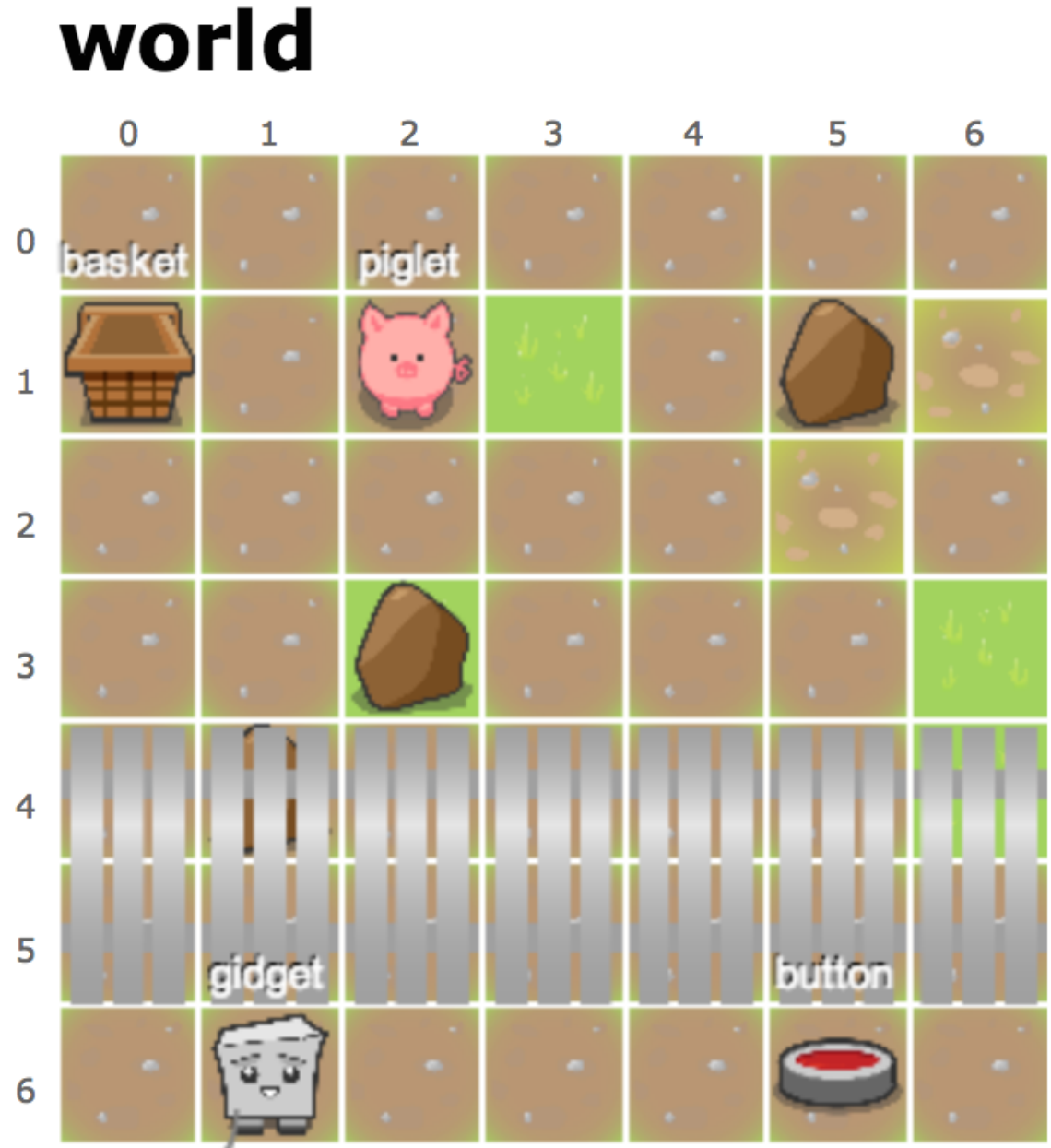
Written in a simple Pythonic language

code

Original Code

```
goto /button/
say "Let's click the button to s
/button/:openFence()
function getPiglet()
    goto /piglet/
    set /piglet/:nickname to "w
    set /piglet/:age to 3
    grab /piglet/
getBird()
getThePiggy()
goto /basket/
```

Programs operate on objects, each with properties and functions



Let's figure out how to open the **gate** with the **button**, and give that **piglet** some new properties before

```
getThePiggy()
goto /basket/
```

```
ensure /piglet/:nickname = "babe"
ensure /piglet/:age = 3
ensure # /piglet/ on /basket/ = 1
```

5

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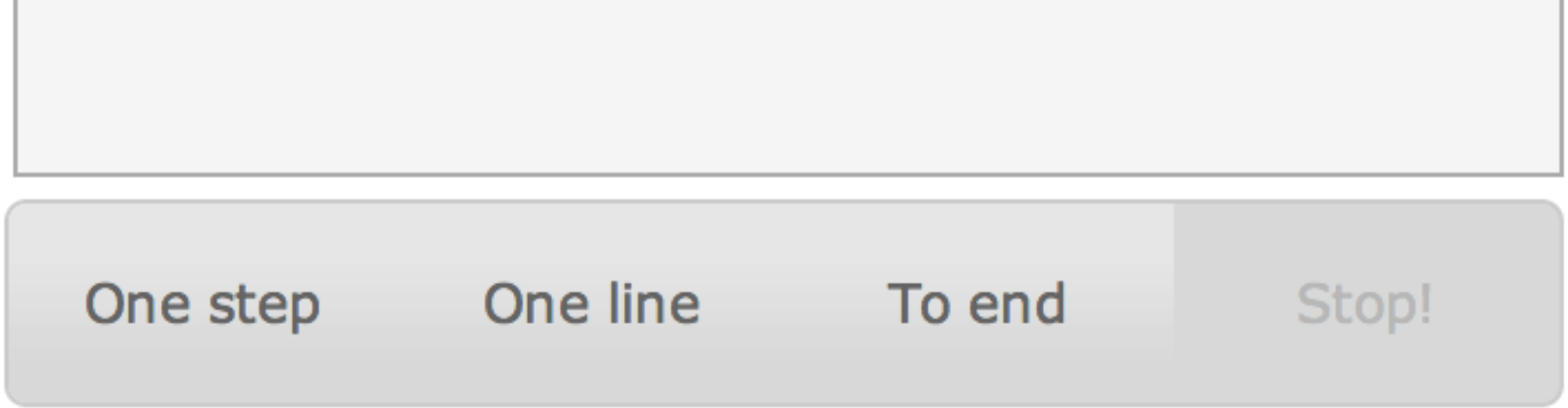
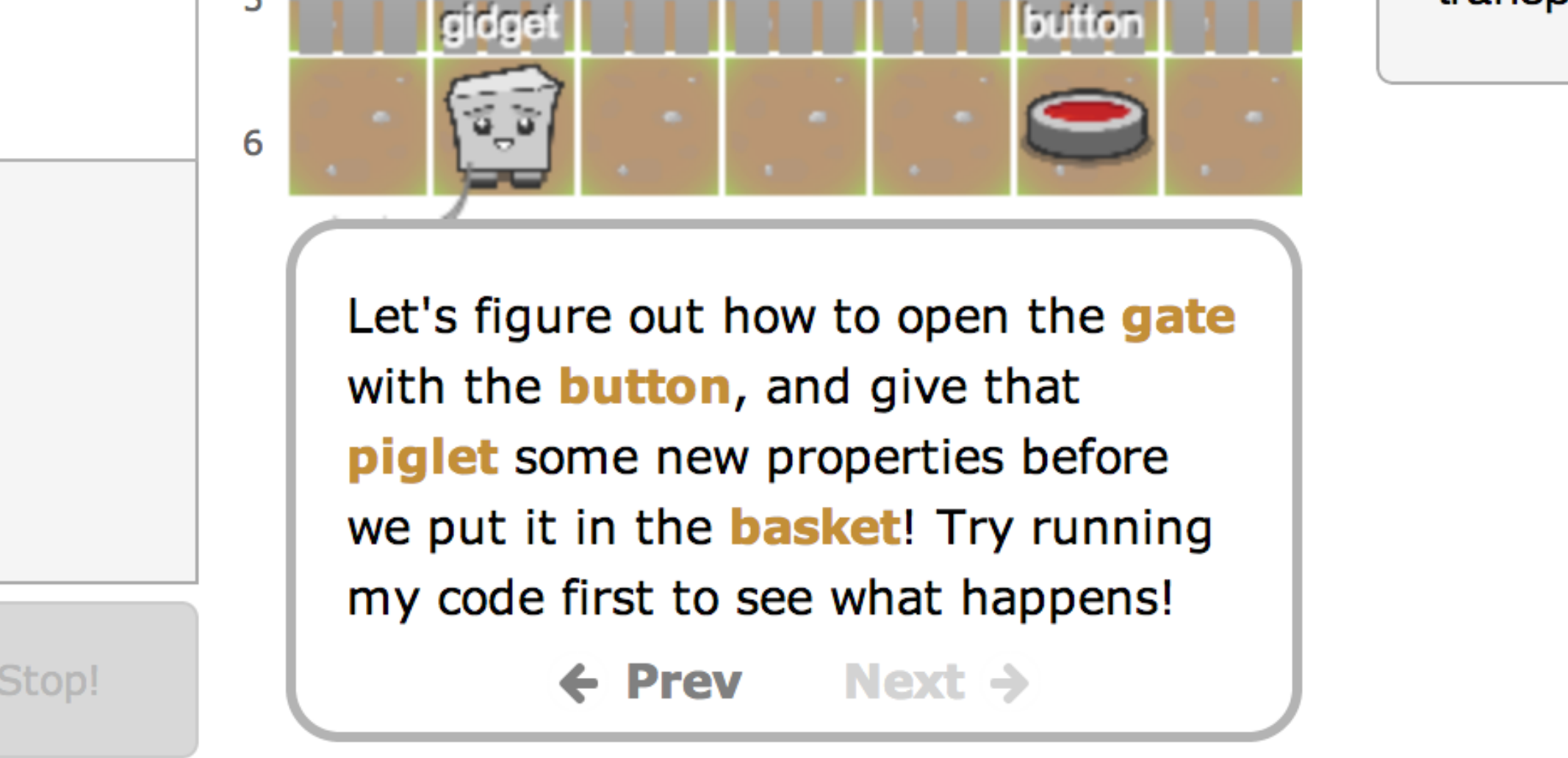
Passing the test cases means passing the level



Program can be executed one instruction at a time, showing player exactly how the program executes



Gidget provides explanations about language semantics and goals after each instruction executes

gidget

energy	100
grabbed	[ ]
image	"default"
labeled	true
layer	1
name	"gidget"
position	[6, 1]
rotation	0
scale	1
transparency	1

Object state and call stack are fully inspectable

Each instruction's operations are highlighted and explained

Context-sensitive documentation on language syntax and semantics avoid the need for tools like Stack Overflow

In-context instructional hints on design patterns and debugging strategies

code

Original Code | Clear Code

```
goto /button/
say "Let's click the button to see its function
/button/:openFence()
function getPiglet()
    goto /piglet/
    set /piglet/:nicknam
    set /piglet/:age to 3
    grab /piglet/
getBird()
getThePiggy()
goto /basket/
```

```
ensure /piglet/:nickname
ensure /piglet/:age = 3
ensure # /piglet/ on /bask
```

world

drag to reposition

Here's a hint...

Are you trying to write and use functions? Try something like this:

```
function reset(myobject)    ! These lines are
    goto myobject           ! for step 1
    set myobject:scale to 1
reset(/goop/)       ! the function can be used for the goop,
reset(/bird/)       ! then reused for the bird!
```

Functions allow you to write code once and then use it multiple times by referring to its name.

1. First, write the function definition.
   1.1 Type the keyword "function".
   1.2 On the same line as "function", type the name you want to give to the function, followed by parentheses.
   1.3 If you want to use parameters, type the

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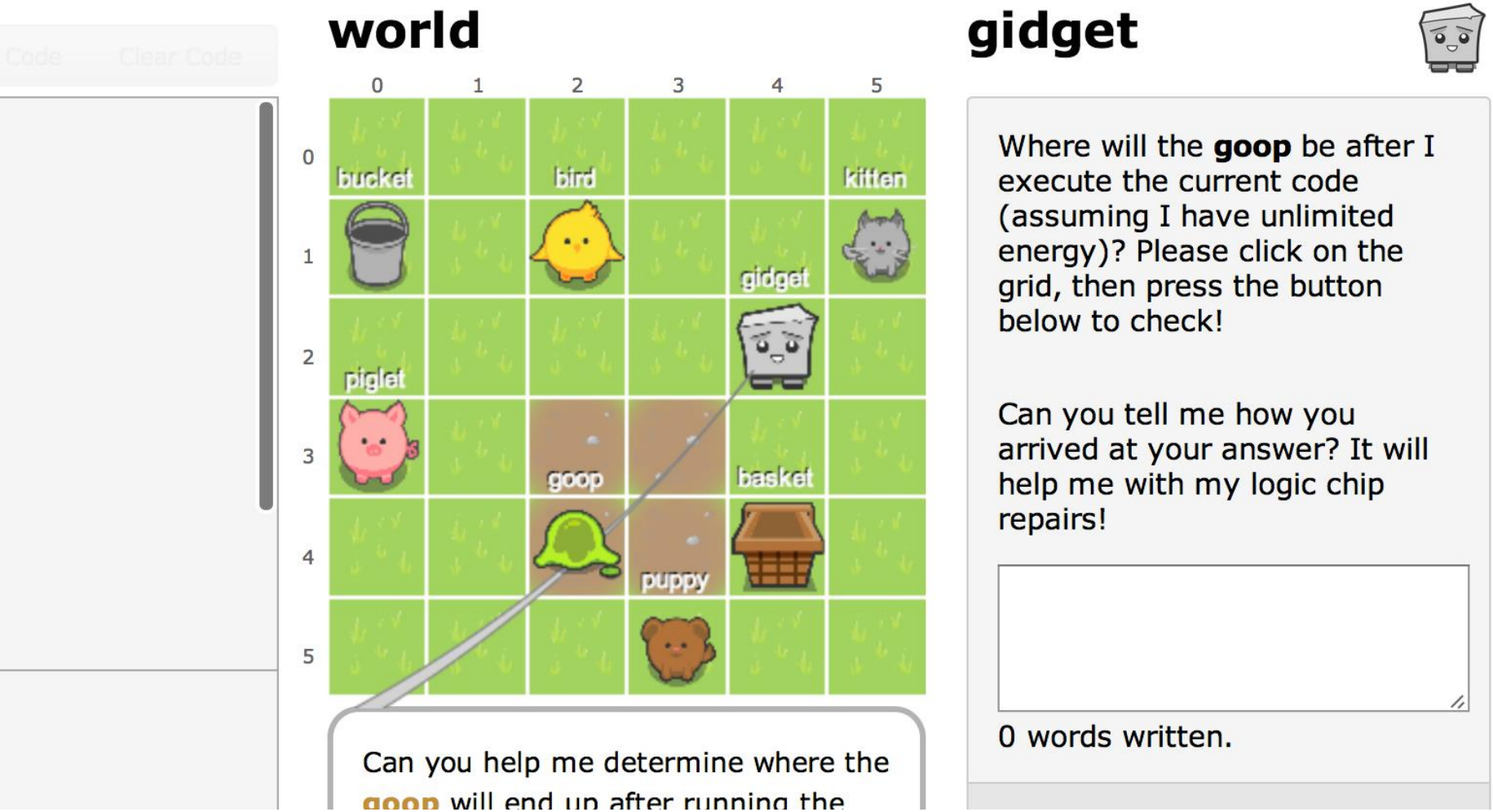
tra

e **gate**
: **piglet**
: put it



In-game assessments provide positive feedback on learning, testing ability to mental simulate program execution and language semantics

Playing the game is equivalent to debugging

Understand the tests

Execute the program

Reproduce the problem

Localize the defects(s)

Write a patch that passes the tests

Curriculum

Across 27 levels, players learn

Variables, conditionals, loops, functions, object-orientation

Reproduction, testing concepts, procedural algorithm design, debugging strategies

Do players learn?

Yes!

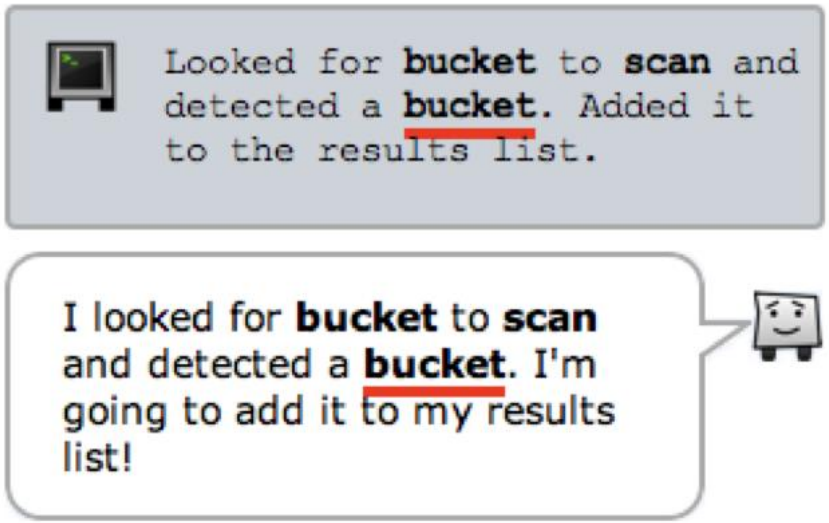
Pre-post test into the game to measure CS1 learning gains

Preliminary results. Just 5 hours of game play produces comparable learning outcomes to weeks of CS 1 instruction

Study in progress

Why is it effective?

The game redirects player's attention to contextually appropriate instruction by framing Gidget as a collaborator

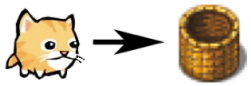


When Gidget has a face and uses personal pronouns, players play twice as long and repair defects twice as fast

Lee, M.J. and Ko, A.J. (2011). Personifying Programming Tool Feedback Improves Novice Programmers' Learning. International Computing Education Research Workshop (ICER), 109-116.

Why is it effective?

The game leverages recent work on preferential attention to focus player attention on the right data

Condition	Goal (Level 1)	Respective Game Images
Inanimate	*block on bin*	
Invertebrate	*beetle on jar*	
Vertebrate	*kitten on basket*	

Players who manipulate animate objects play <u>twice as long and fast</u> as players who manipulated inanimate objects

Lee, M.J. and Ko, A.J. (2012). Investigating the Role of Purposeful Goals on Novices' Engagement in a Programming Game. IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC), 163-166.

Why is it effective?

Contextual instruction on debugging and problem solving:

Used to immediately attend to & fix anti pattern and potential errors

Used to create a mental to-do list

Is it fun?

Lee, M.J. and Ko, A.J. (2011). Personifying Programming Tool Feedback Improves Novice Programmers' Learning. International Computing Education Research Workshop (ICER), 109-116.

Over 500 rank novice programmers have played on Mechanical Turk for an average of ~60 minutes (paid $0.05/level)

"It did not even seem like I was learning programming. It truly felt like I was just playing a game. I tend to become frustrated easily yet this held my attention and made it so I didn't want to give up."

Is it fun?

Charters, P., Lee, M.J., Ko, A.J., Loksa, D. (2014). Challenging Stereotypes and Changing Attitudes: The Effect of a Brief Programming Encounter on Adults' Attitudes toward Programming (2014) ACM Symposium on Computer Science Education,

In pre/post surveys from 200 players:

Attitudes prior to the game were negative

"Programming is complicated and boring."

Attitudes toward programming improved significantly, becoming positive

"I now know that programming can be fun and easy, also anyone can do it."

Change occurred regardless of gender, population density, or level of education.

4 week long summer camps

Two co-ed in Corvallis, OR

Two girls only in Seattle, WA

72 teens age 12-17

50 girls signed up

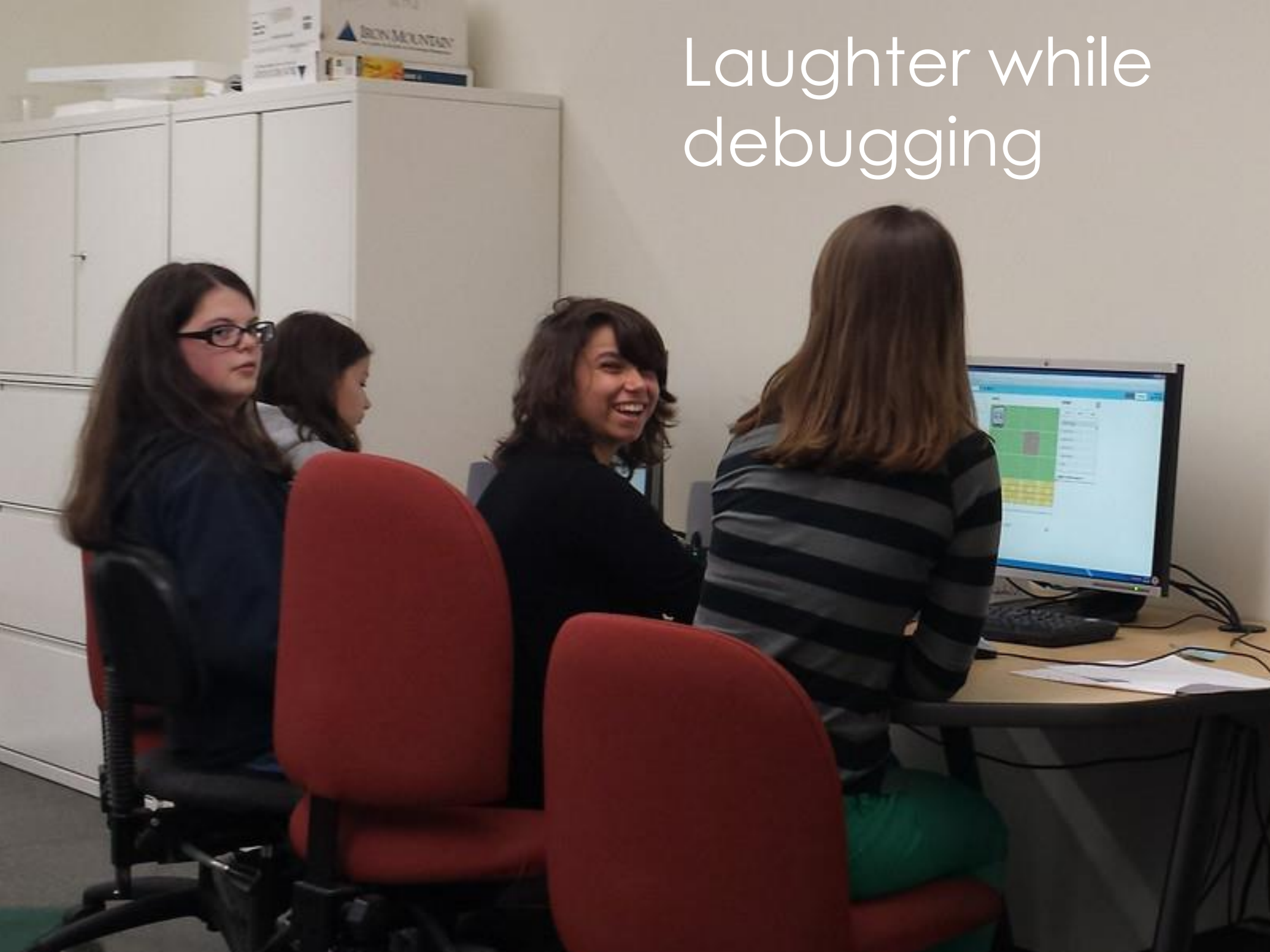
Played the game in pairs

3 days to complete game

2 days to design new levels to challenge friends and family

Lee, M.J., Bahmani, F., Kwan, I., LaFerte, J., Charters, P., Horvath, A., Luor, F., Cao, J., Law, C., Beswetherick, M., Long, S., Burnett, M.M., Ko, A.J. (2014). Principles of a Debugging-First Puzzle Game for Computing Education. IEEE Symposium on Visual Languages and Human-Centric Computing, to appear.

Laughter during a pre-test


Laughter while debugging

Laughter while writing new levels


Learners strongly motivated by to challenging their parents

Future work

Can debugging games teach advanced programming languages and skills?

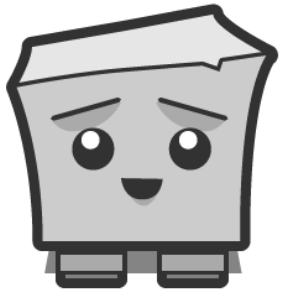
Can we generate puzzles that optimize learning *and* engagement?

Can we improve learning through pair debugging?

Can we engage player's social networks through viral learning?

Public release this Fall

helpgidget.org



Hi! I'm Gidget.

I'm going on a mission soon, but sometimes I make silly mistakes and can't fix them by myself. Will you come back and help me when I'm ready to go?

Questions?

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