Learning Programming

SWE 795, Fall 2019
Software Engineering Environments

GEORGE MASON UNIVERSITY

Today

- Part 1 (Lecture)(~40 mins)
- Part 2 (2 HW4 presentations)(36 mins)
- Break!
- Part 3 (3 HW4 presentations)(54 mins)
- Part 4 (Feedback and course evals)(20 mins)

Overview

- What makes learning programming hard?
- Tools & languages for learning programming
  - Simplify typing code
  - Understand program execution
  - Offer context-specific help
  - Motivate learning programming

What makes learning programming hard?

- What makes programming hard?
  - Is the challenge thinking computationally?
  - Or in understanding how to formally express computation in a programming language?

Slides partially adapted from Human Aspects of Software Development, Spring 2011, Lecture 11: How do people naturally think about computation? (Cyrus Omar)

Programming is difficult

Difficult to learn

30% of students fail or withdraw from CS1

Difficult to do well

> Write a [Pascal] program that repeatedly reads in positive integers, until it reads the integer 99999. After seeing 99999, it should print out the average.
>
> *Rainfall Problem* [Soloway et al, 1983]

14% of CS1 students (3/4 through course)
36% of CS2 students (3/4 through course)
69% of students in Jr./Sr. Systems course

Adapted from

Why is this hard?

- Conceiving a solution?
  - Q: Can people develop natural language solutions to programming problems?
- Formalizing the solution?
  - Q: Are languages & APIs intuitive?

Can people develop natural language solutions to programming problems?

Write a [Pascal] program that repeatedly reads in positive integers, until it reads the integer 99999. After seeing 99999, it should print out the average.

Rainfall Problem [Soloway et al, 1983]

```
repeat
    Sum := 0 + I
    N := 1
    Sum := I + I
    N := 2
until I = 99999
```

Even though the subject seems fairly confused about how to express the program in Pascal, he has a very clear idea about the actions needed for a correct solution. We have found that this is typical -- novice programmers are not totally confused about what needs to be done, just about how to express that need.

[Bonar & Soloway, 1983]

Can people develop natural language solutions to programming problems?

Goal: Create directions for somebody else.

Make one list of employees who meet either of the following criteria:

(1) They have a job title of technician and they make 6 dollars/hr. or more.
(2) They are unmarried and make less than 6 dollars/hr.

List should be organized by employee name.

[Miller, 1981]

- **Successful**: other humans could accomplish tasks with their instructions
- **Set operations**, not loops: "For all the last names starting with G…"
- **If operations**, but no **else**.

Can people develop natural language solutions to programming problems?

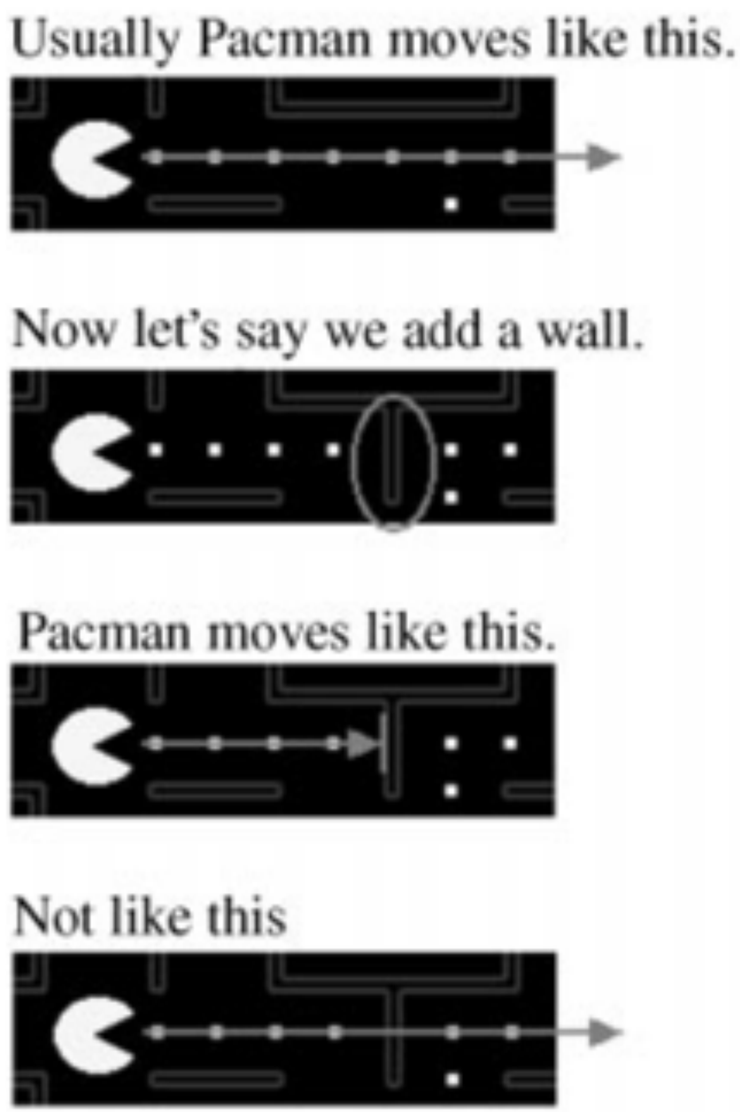
Children (aged 11 and 12) played a short 3D role-playing game and were asked to describe the rules of the game.

Figure 2. Errors in triggers and outcomes

Yes, but…

- Lots of **imprecision** and **underspecification**
- Novices assume that instructee will interpret instructions intuitively.

Intuitions about programming language constructs



Do this: Write a statement that summarizes how I (as the computer) should move Pacman in relation to the presence or absence of other things.

- Twelve fifth graders in a Pittsburgh public elementary school
- Equally divided amongst boys and girls
- No prior experience programming
- *"The participants received no reward other than the opportunity to leave their normal classroom for half an hour and the opportunity to play a computer game for a few minutes."* ☺

[Pane et al., 2001]

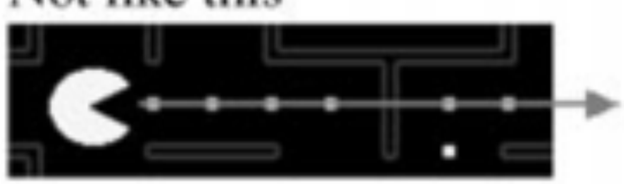
Intuitions about programming language constructs

Usually Pacman moves like this.

Now let's say we add a wall.

Pacman moves like this.

Not like this



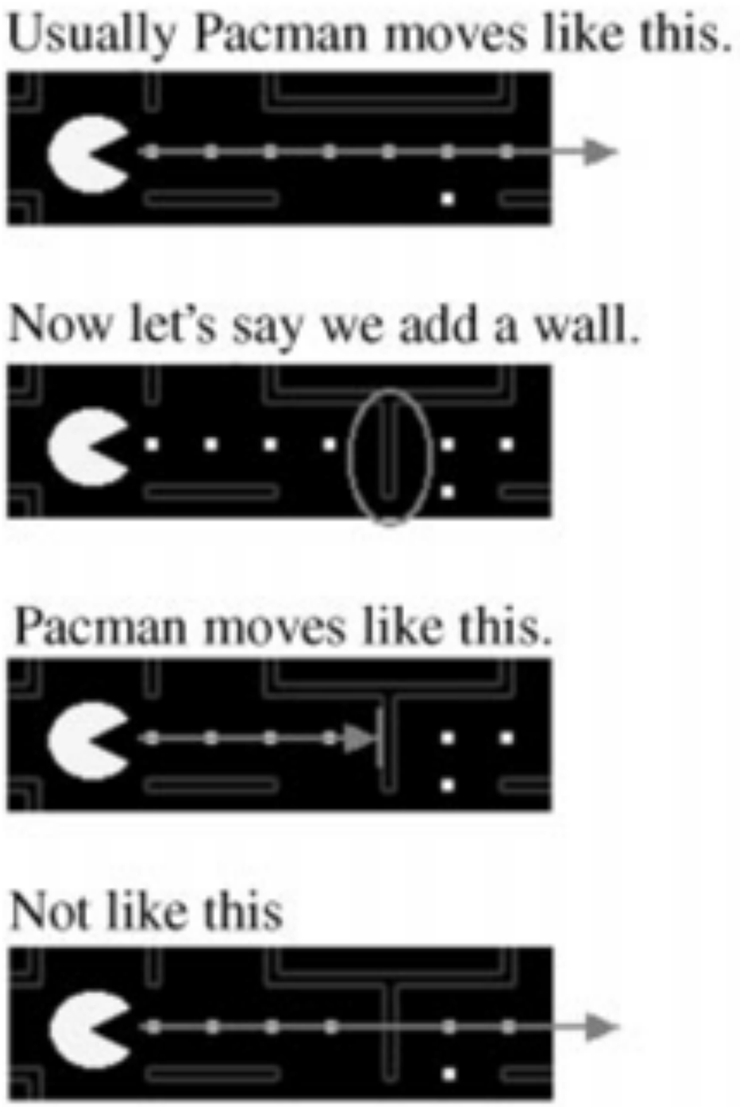
Do this: Write a statement that summarizes how I (as the computer) should move Pacman in relation to the presence or absence of other things.

Programming Style

- **54%** - production rules or event-based, beginning with *when*, *if* or *after*.
  - *When PacMan eats all the dots, he goes to the next level.*
- **18%** - global constraints
  - *PacMan cannot go through a wall*
- **16%** - declarations/other
  - *There are 4 monsters.*
- **12%** - imperative
  - *Play this sound. Display this string.*

[Pane et al., 2001]

Intuitions about programming language constructs



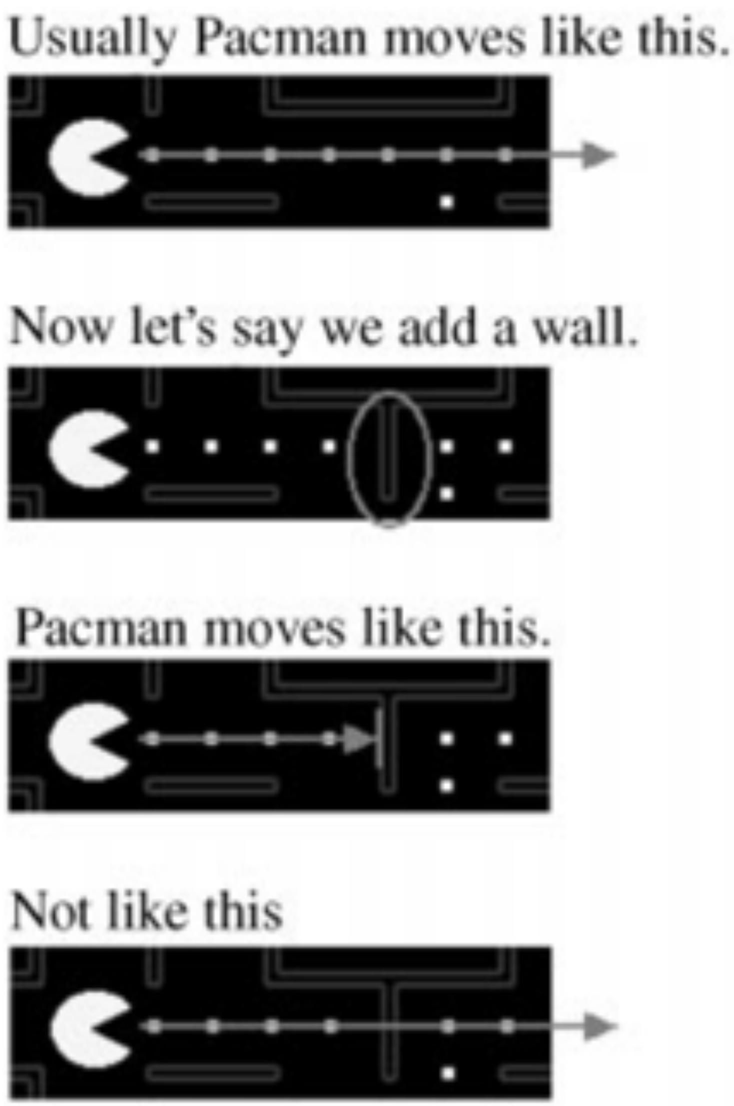
Do this: Write a statement that summarizes how I (as the computer) should move Pacman in relation to the presence or absence of other things.

Modifying State

- **61%** - behaviors were built into the entity, e.g. OO
  - *Get the big dot and the ghost will turn colors…*
- **20%** - direct modification of properties
  - *After eating a large dot, change the ghosts from original color to blue.*
- **18%** - other

[Pane et al., 2001]

Intuitions about programming language constructs



Do this: Write a statement that summarizes how I (as the computer) should move Pacman in relation to the presence or absence of other things.

OR

- **63%** - boolean disjunction
  - *To make PacMan go up or down, you push the up or down arrow key*
- **20%** - clarifying or restating the prior item
  - *When PacMan hits a ghost or a monster, he loses his life.*
- **18%** - meaning *otherwise*
- **5%** - other

[Pane et al., 2001]

Intuitions about programming language constructs

No.	First name	Last name	Average score	Performance
1	Sandra	Bullock	3000	
2	Bill	Clinton	60000	
3	Cindy	Crawford	500	
4	Tom	Cruise	5000	
5	Bill	Gates	6000	
6	Whitney	Houston	4000	
7	Michael	Jordan	20000	
8	Jay	Leno	50000	
9	David	Lettermen	700	
10	Will	Smith	9000	

Question 5A
- Describe in detail what the computer should do to obtain these results.

No.	First name	Last name	Average score	Performance
1	Sandra	Bullock	3000	Fine
2	Bill	Clinton	60000	Extraordinary
3	Cindy	Crawford	500	Poor
4	Tom	Cruise	5000	Fine
5	Bill	Gates	6000	Fine
6	Whitney	Houston	4000	Fine
7	Michael	Jordan	20000	Extraordinary
8	Jay	Leno	50000	Extraordinary
9	David	Lettermen	700	Poor
10	Will	Smith	9000	Poor

FIGURE 3. Depiction of a problem scenario in study two.

Insertion into a data structure

- **75%** - no mention of making room for new element
  - *Put Elton John in the records in alphabetical order*
- **16%** - make room for element before inserting it
  - *Use the cursor and push it down a little and then type Elton John in the free space*
- **6%** - make room for element after inserting it
- **4%** - other

[Pane et al., 2001]

Is natural language programming a solution?

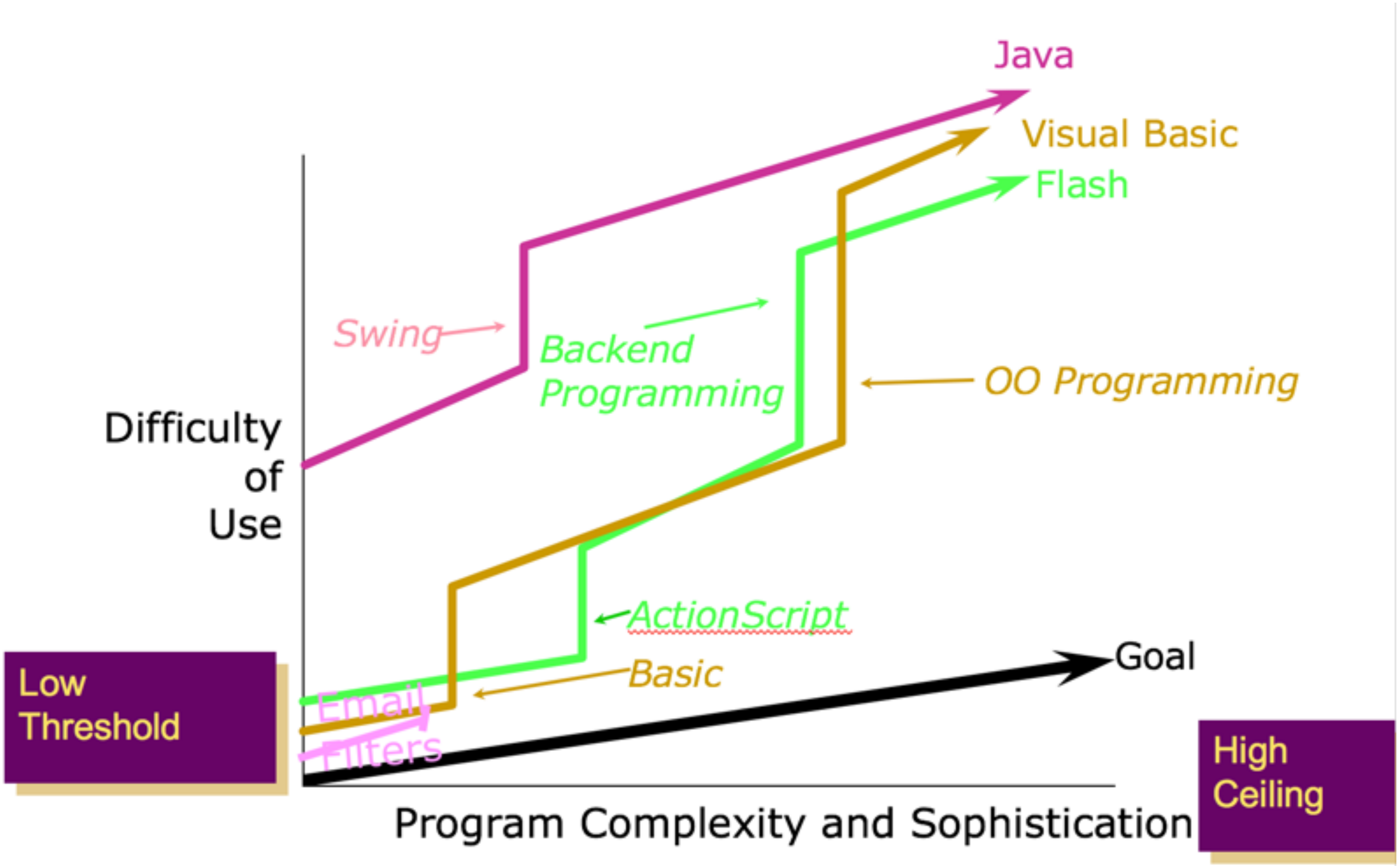
A **difficult proposition** – natural language is complex and imprecise

- Computer and programmer do not have a shared context [Nardi, 1993]; programmers cannot use rules of cooperative conversation [Grice, 1975]
- Not obvious where the computer's limits are

Novices **can use formal languages** if designed carefully [Bruckman and Edwards, 1999]

- Describing the instructee as a naïve alien increases precision of instructions [Galotti, 1985]
- Anthropomorphizing computers is counterproductive [du Boulay, 1989]

Goal: Gentle Slope Systems



Myers, B.A., Smith, D.C., and Horn, B. “Report of the `End-User Programming' Working Group,” in *Languages for Developing User Interfaces. 1992. Boston, MA: Jones and Bartlett. pp. 343-366.*

Minimalist Learning Theory

- *Choose an action-oriented approach*
  - Provide an **immediate** opportunity to act, encourage self-directed exploration & innovation, prioritize **user's** goals over delivery of information
- *Anchor the learning tool in the task domain*
  - Use **real** tasks as instruction, organize instruction around task steps
- *Support error recognition & recovery*
  - Prevent mistakes when possible, provide error information that offers not only detection but 'on-the-spot' diagnosis & recovery
- *Support reading to do, study, locate*
  - Make instructions brief & self-contained to support different levels of engagement

Carroll, J. (1990) The Nurnberg Funnel: Designing Minimalist Instruction for Practical Computer Skill. MIT Press, Cambridge, MA.

Problem frames

- Developers approaching messy problem interpret it with a *frame*
- Imposes boundaries on what learners will consider

Simplify typing code

- If key barrier is syntax, reduce challenge of working with syntax
  - Reduce constructs in programming language
  - Simplify constructs in programming language
  - Eliminate possibility of syntax errors

Beginners All-Purpose Symbolic Instruction Code (BASIC, 1963)

- Support a subset of instructions & remove unnecessary syntax
- Offer rapid feedback through interpreted language
- Offer simplified statements w/ 3 parts: line number, operator, operands

FORTRAN:

```
      do 30 i = 1, 10
         m = m + I
30    continue
```

BASIC:

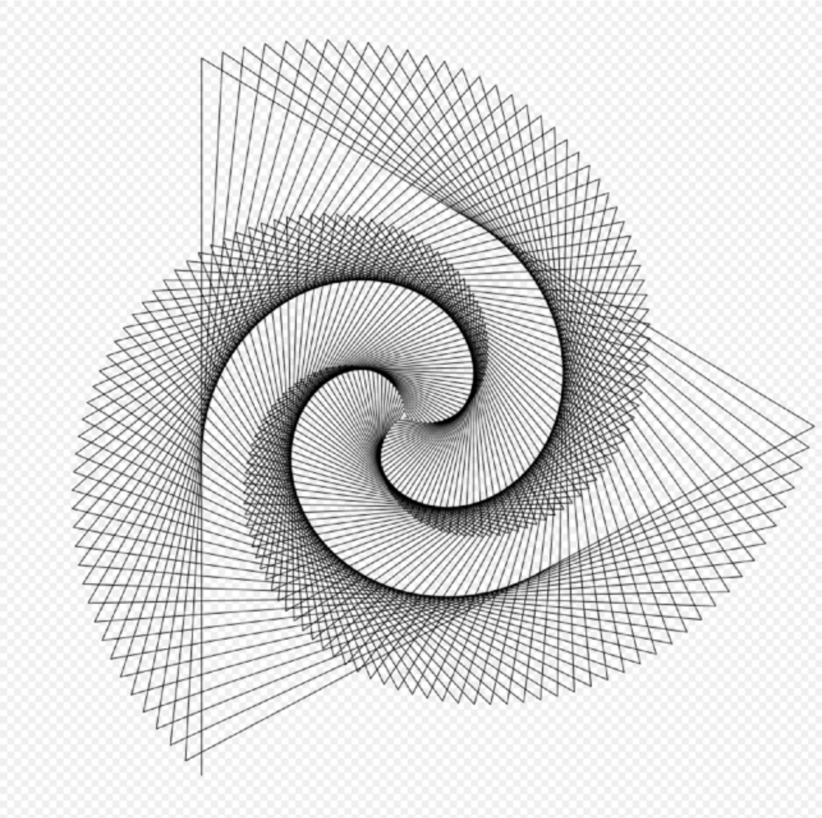
```
100 FOR I = 1 TO 10
110 LET S = S + I
120 NEXT I
```

Figure 2. A *for* loop to compute the sum of the numbers from 1 to 10 written in FORTRAN and BASIC.

J.G. Kemeny and T. Kurtz, Dartmouth College, 1963

LOGO (1967)

- Supports manipulating turtle to draw pictures
  - Move forward 10 spaces
  - Turn left 90 degrees
- Offers dialect of LISP with less punctuation
- Supports creating music, translating languages, and much more



By 414owen - Own work, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=51472272

Seymour Papert, MIT, 1967

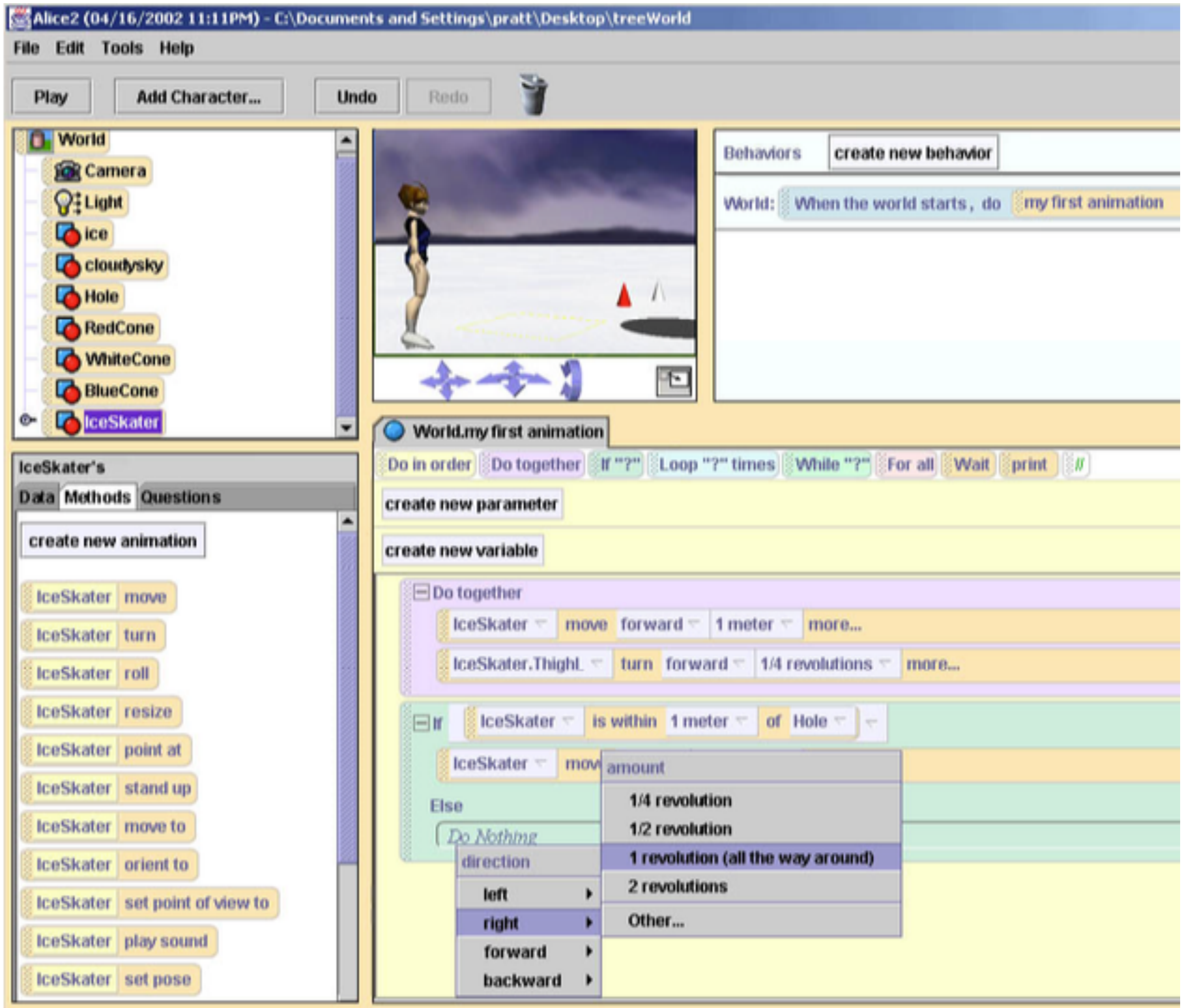
Interacting with objects

Figure 4. A view of the My Magic Castle courtyard. The user is creating the rule "Nicky should dance when it meets the horse."

- Enable users to create objects & rules on how objects behave

My Make Believe Castle: Logo Computer Systems Incorporated, 1995 [LCSI, 1995]

Structured editors

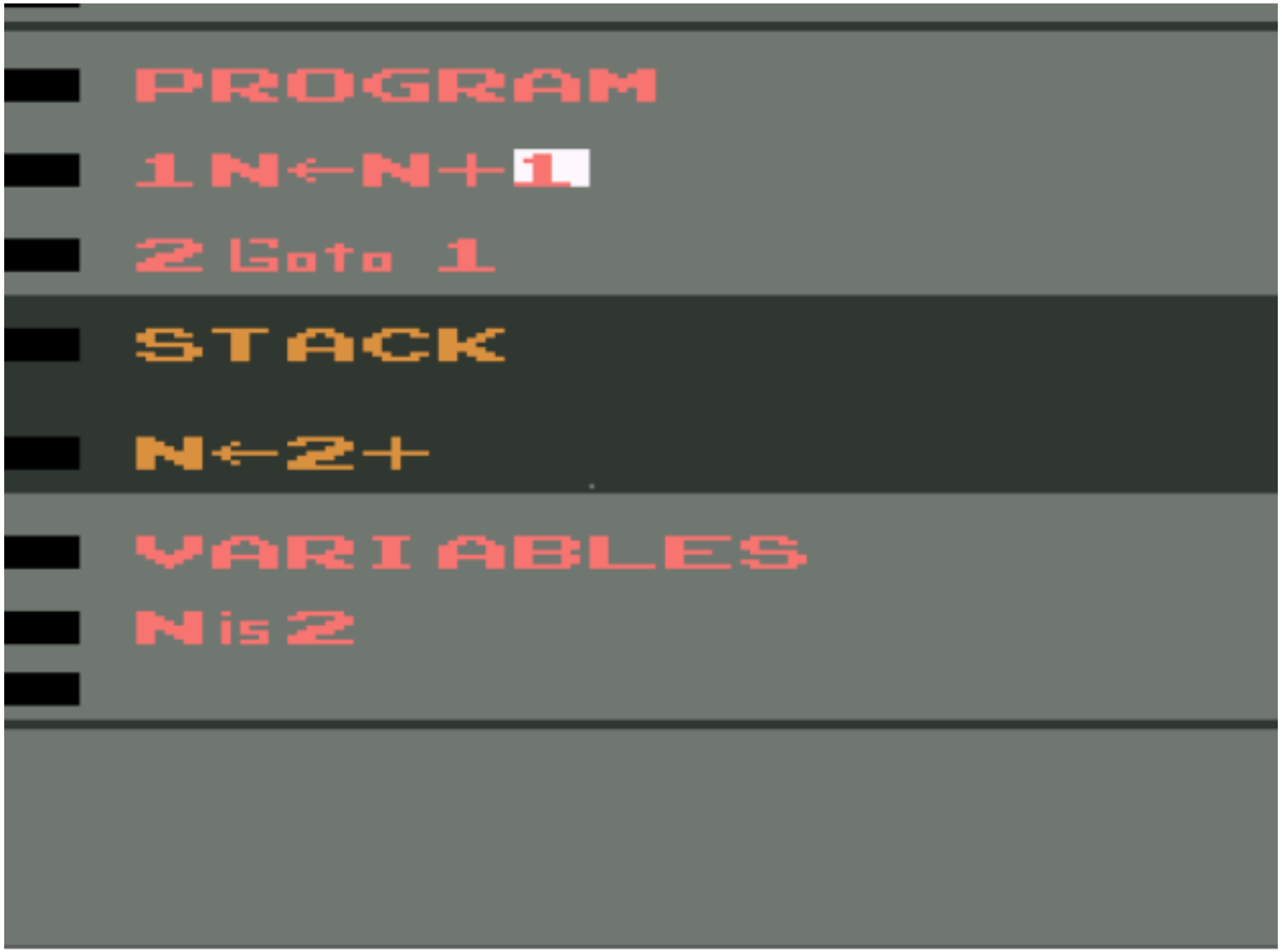


Alice 2, 2002

Understand program execution

- Execution of program is hidden
    - Forces novices to simulate execution of program
    - Novices may simulate execution incorrectly
- Offer novice programmers visibility into the current execution state of programs

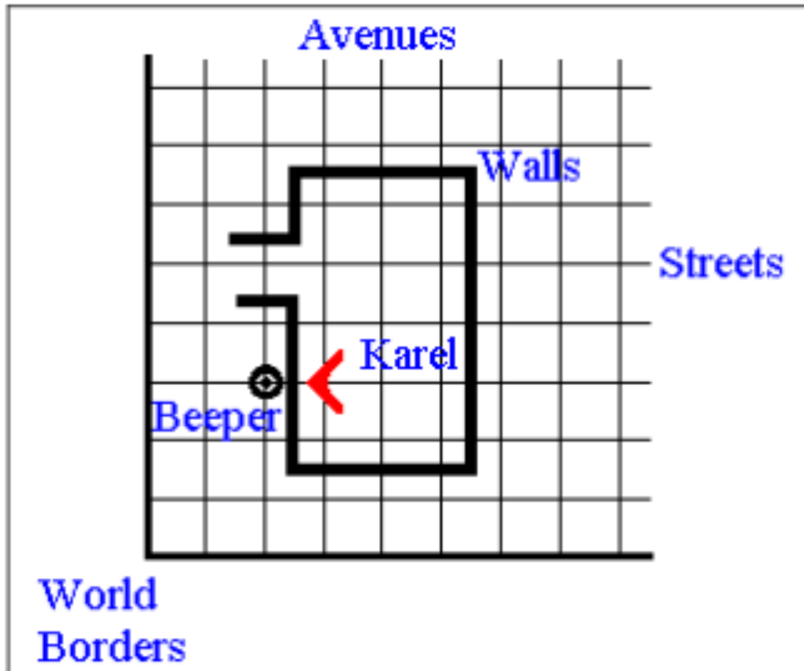
ATARI 2600 BASIC (1979)



- Stack: displays expressions as evaluated, updating as cursor changes
- Variables: displays variables and values

Make programming concrete through micro-worlds: Karel

- Actors can only perform a few actions
- Include simulations that allow students to watch progress of actors
- Enables students to gain familiarity with control structures like conditionals & loops




```
BEGINNING-OF-PROGRAM
  DEFINE-NEW-INSTRUCTION
turnright AS
    ITERATE 3 TIMES
      turnleft;

  BEGINNING-OF-EXECUTION
    turnright;
    ITERATE 2 TIMES
      move;
    turnleft;
    ITERATE 2 TIMES
      move;
    turnleft;
    ITERATE 2 TIMES
      move;
    turnleft;
    move;
    pickbeeper;
    turnoff;
  END-OF-EXECUTION
END-OF-PROGRAM
```

Figure 15. Left, a simple Karel world with Karel in a room and a beeper outside the door. On the right, a program that will move Karel to the beeper's location and have him pick up the beeper.

PATTIS, R. E. 1981. Karel the Robot: A Gentle Introduction to the Art of Programming with Pascal. New York, John Wiley and Sons.

Offer context-specific help

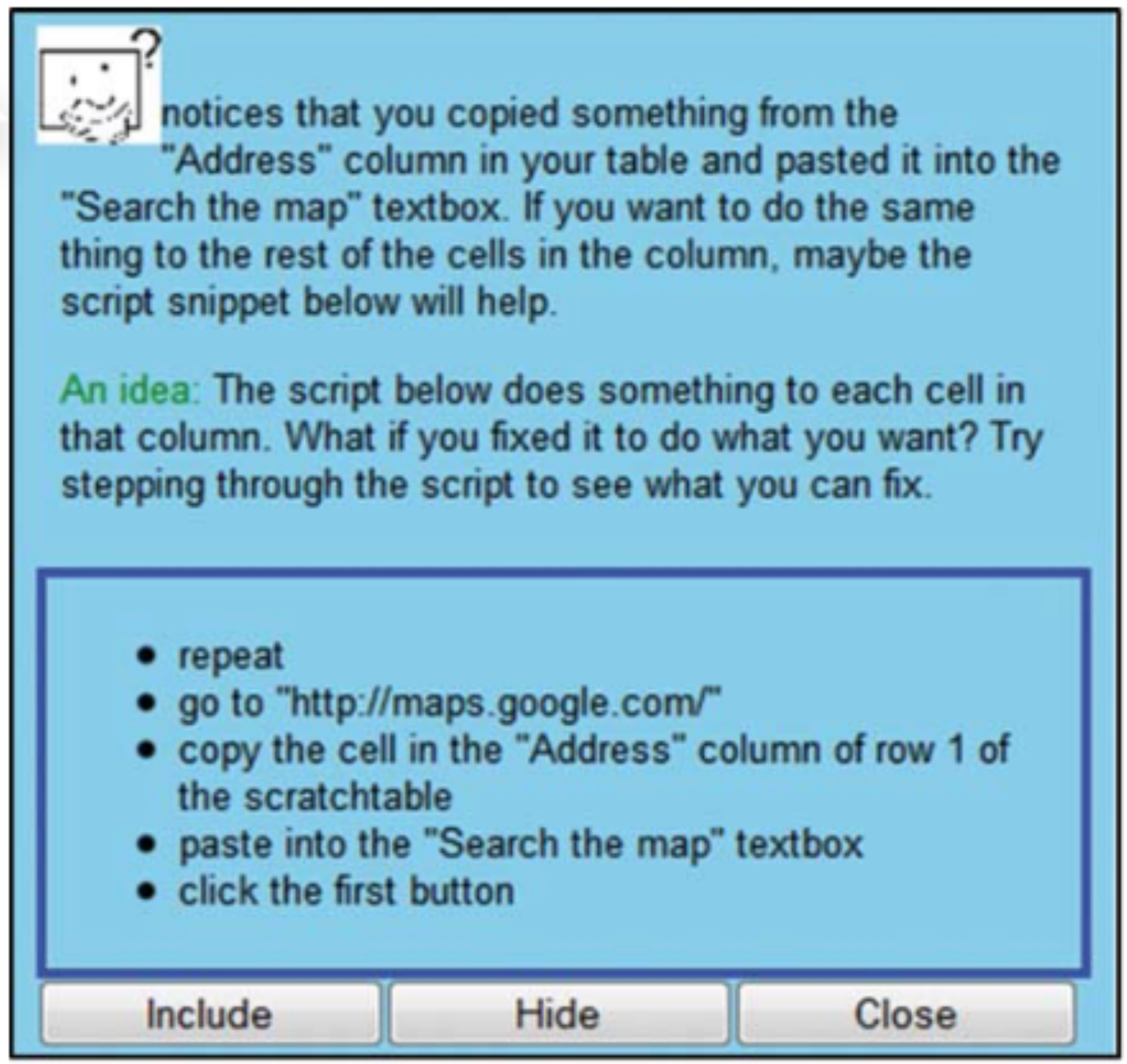
- Learners experience breakdowns & barriers that prevent progress on tasks
- Offer specific actions learners can take to make progress when they experience these

Stencils-based tutorials

- Compared to paper tutorials, enable students to complete tutorials 26% faster w/ fewer errors & less human assistance

Caitlin Kelleher and Randy Pausch. 2005. Stencils-based tutorials: design and evaluation. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '05). ACM, New York, NY, USA, 541-550.

Idea Garden



Jill Cao, Scott D. Fleming, Margaret Burnett, Christopher Scaffidi; Idea Garden: Situated Support for Problem Solving by End-User Programmers. *Interact Comput* 2015; 27 (6): 640-660.

Show execution state: Python Tutor

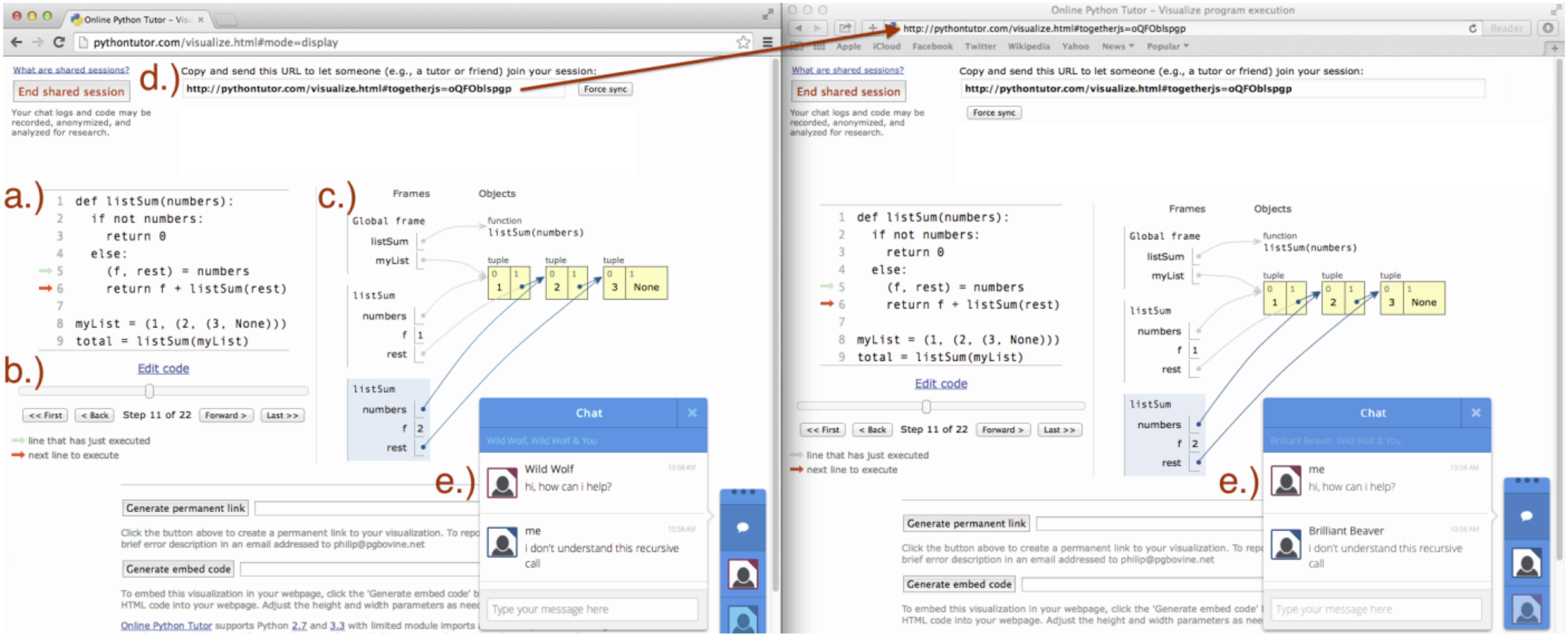


Fig. 2. Overview of our Codechella system, which is built upon the Online Python Tutor program visualization tool [10]. Here is a typical use case: a.) The user writes code in an ordinary Web browser, b.) runs their code and steps forward and backward through execution points, c.) sees a visualization of stack frames, variables, data structures, and pointers at each execution point, d.) clicks the "Start a Codechella session" button and sends a unique URL to a tutor or friend, and then e.) chats with other participants in the Codechella session while navigating the visualization and writing code together in-sync.

https://www.youtube.com/watch?v=CKdUMVNwkYM

Online Python Tutor: Embeddable Web-Based Program Visualization for CS Education. Philip J. Guo. *ACM Technical Symposium on Computer Science Education (SIGCSE)*, 2013.

Codechella: Multi-User Program Visualizations for Real-Time Tutoring and Collaborative Learning. Philip J. Guo, Jeffery White, Renan Zanelatto. *IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC)*, 2015.

Overcode

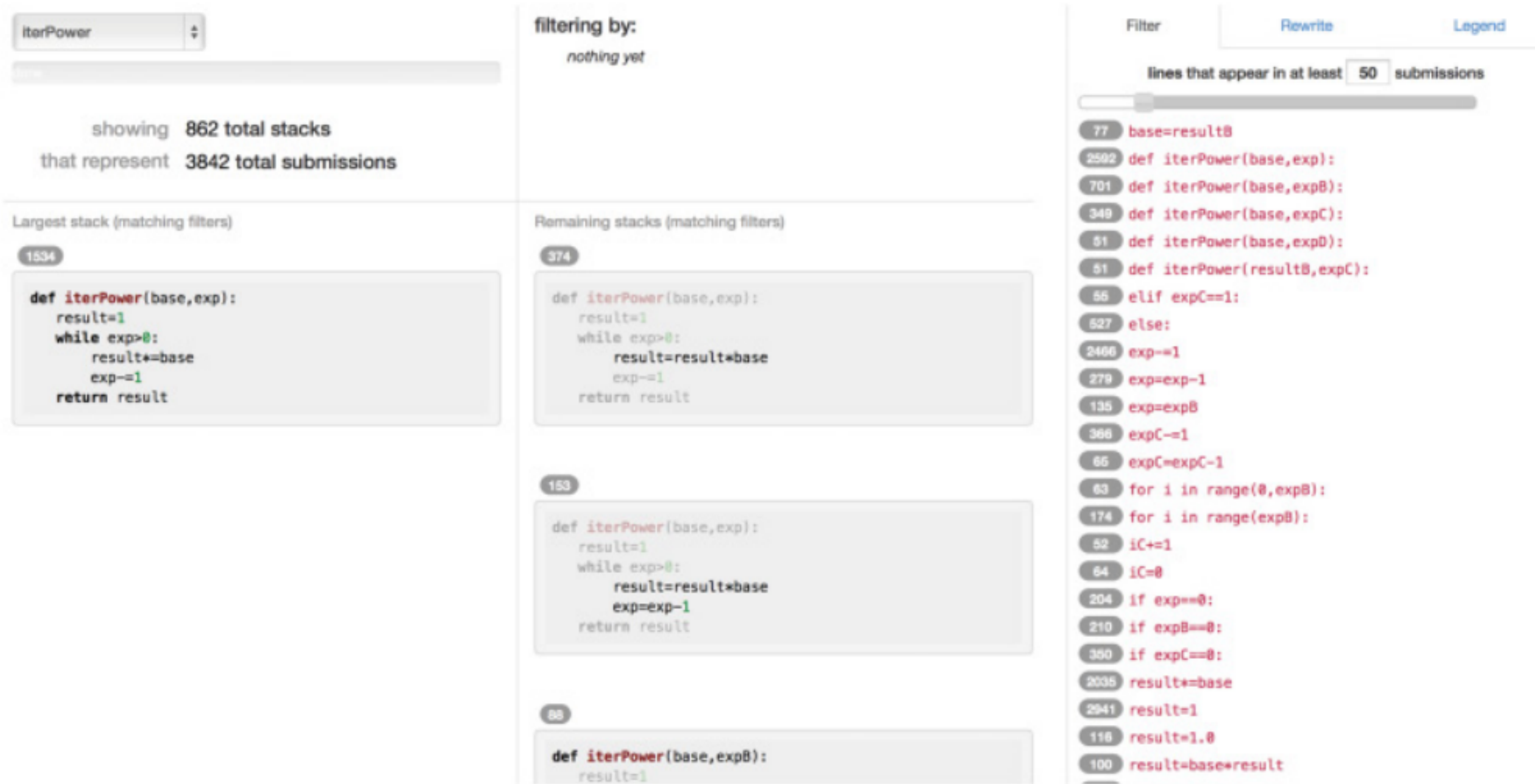


Fig. 1. The OverCode user interface. The top-left panel shows the number of clusters, called *stacks*, and the total number of solutions visualized. The next panel down in the first column shows the largest stack, whereas the second column shows the remaining stacks. The third column shows the lines of code occurring in the cleaned solutions of the stacks together with their frequencies.

https://www.youtube.com/watch?v=6ov_82nxpbQ

Elena L. Glassman, Jeremy Scott, Rishabh Singh, Philip J. Guo, and Robert C. Miller. 2015. OverCode: Visualizing Variation in Student Solutions to Programming Problems at Scale. *ACM Trans. Comput.-Hum. Interact.* 22, 2, Article 7 (March 2015), 35 pages.

Motivating novice programmers

- Typical intro CS courses have assignments about numeric tasks and data structures
- As novices begin to learn programming, unclear why it matters or what is possible

- How can novices be motivated to invest the effort necessary to learn programming?

Storytelling Alice

- Formative study of middle school girls
- Offer high-level animations & support of r multiple scenes
- Offer characters & scenery that spark story ideas
- Offer story-based tutorial

Storytelling Alice	Generic Alice
Say, think	Move
Play sound	Turn
Walk to, walk offscreen, walk	Roll
Move	Resize
Sit on, lie on	Play sound
Kneel	Move to
Fall down	Move toward
Stand up	Move away from
Straighten	Orient to
Look at, Look	Point at
Turn to face, turn away from	Set point of view to
Turn	Set pose
Touch, Keep Touching	Move at speed, turn at speed, roll at speed

Caitlin Kelleher and Randy Pausch. 2007. Using storytelling to motivate programming. *Commun. ACM* 50, 7 (July 2007), 58-64.

Games: Gidget

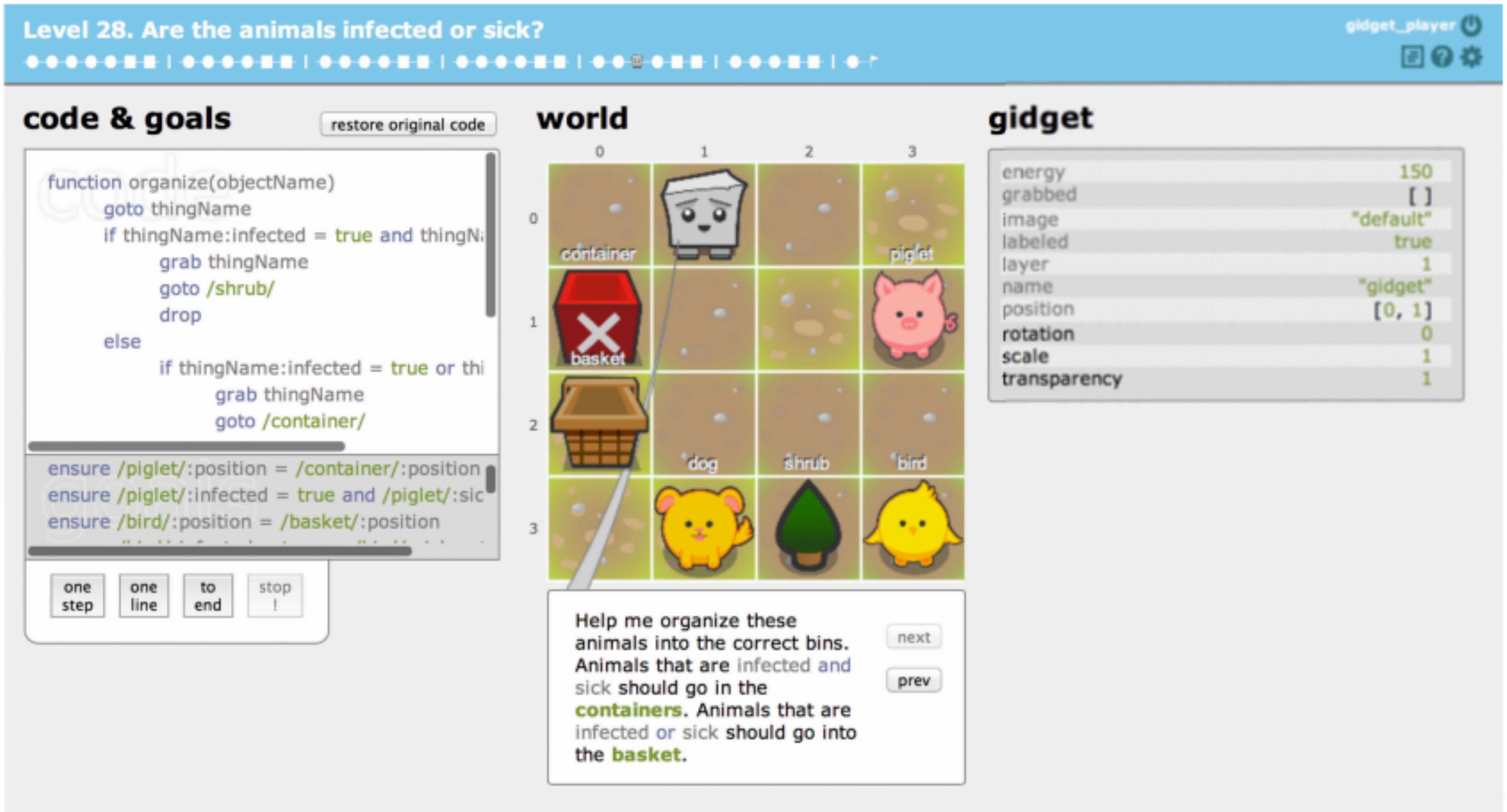
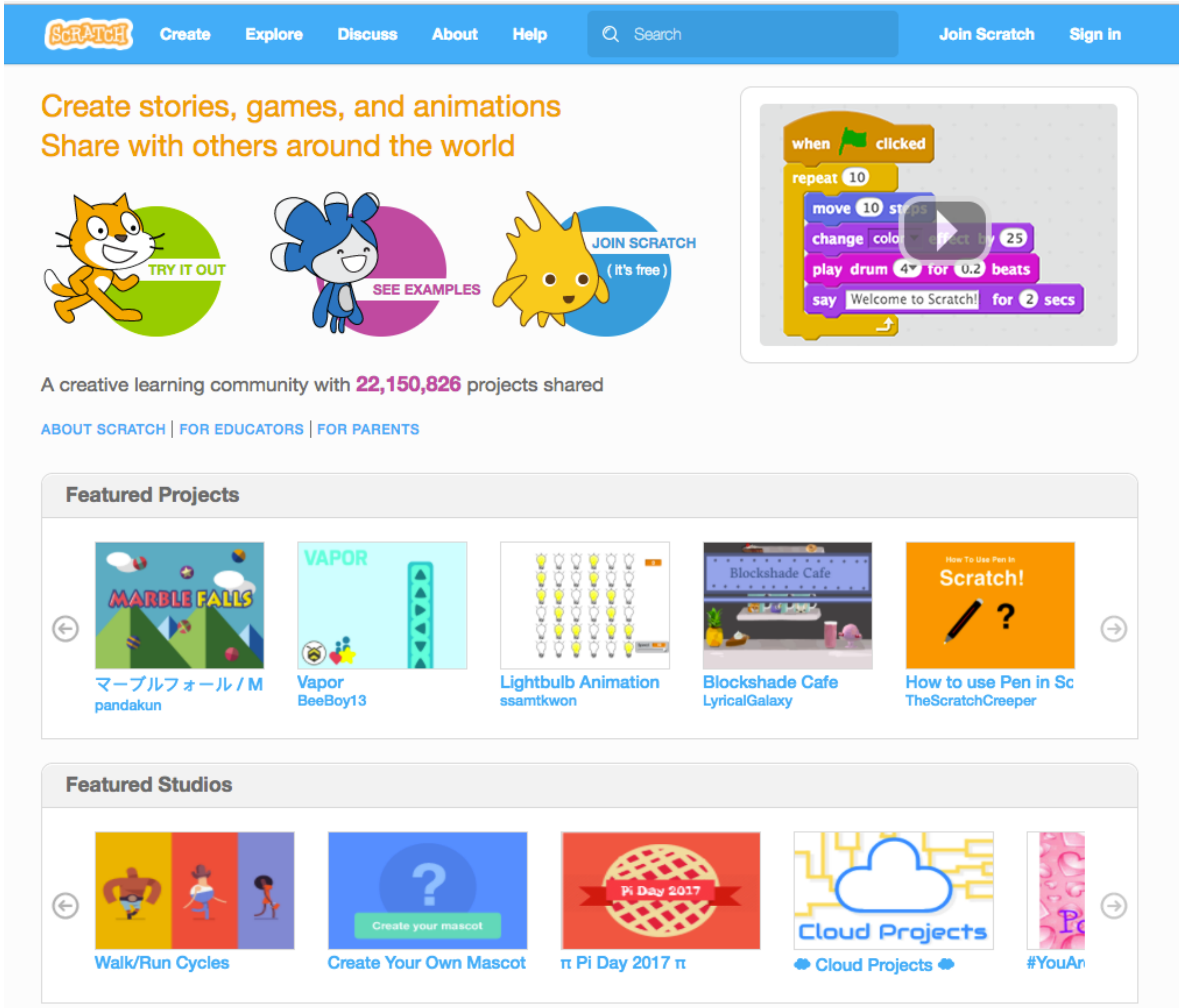


Figure 1. The Gidget game, where learners first help a damaged robot fix its programs by debugging its code (shown above), then create their own programs after completing all the levels.

http://www.helpgidget.org/

M. J. Lee, "Gidget: An online debugging game for learning and engagement in computing education," *2014 IEEE Symposium on Visual Languages and Human-Centric Computing (VL/HCC)*, Melbourne, VIC, 2014, pp. 193-194.

Communities: Scratch



https://scratch.mit.edu/