Taking Stock of Blocks:
Promises and Challenges of Blocks Programming Languages

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October 21, 2015

Alternative Talk Titles that Didn't Quite Make It

Why Blocks Programming Matters

What We Don't Know About Blocks is a Lot

Thinking Outside the Blocks

Talk Road Map

- Motivation: Democratizing Programming
- What are Blocks Programming Languages?
  Demo, History, State of the Art
- Lowering barriers with blocks
  - Syntax
  - Static semantics
  - Dynamic semantics
- Outside the Blocks
- Challenges in blocks programming
  - Usability
  - Learnability in blocks vs. text
  - Perception: blocks programming not "real", maybe harmful

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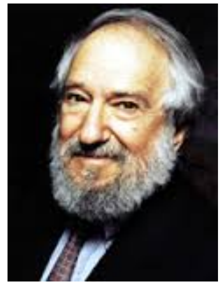
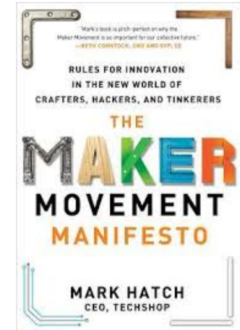
Papert on Constructionism

"The word **constructionism** is a mnemonic for two aspects of the theory of science education underlying this project … **learning is most effective when part of an activity the learner experiences as constructing is a meaningful product**." *Constructionism: A New Opportunity for Elementary Science Education (bolding mine)*

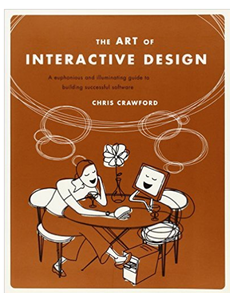


Maker Movement

"**You can innovate as a hobby. Imagine that: a nation of innovation hobbyists working to make their lives more meaningful and the world a better place.** Welcome to the maker revolution."
— Mark Hatch, The Maker Movement Manifesto: Rules for Innovation in the New World of Crafters, Hackers, and Tinkerers (bolding mine)



Democratizing Programming



"What we need is a means of democratizing programming, of taking it out of the soulless hands of the programmers and putting it into the hands of a wider range of talents."
Chris Crawford,
The Art of Interactive Design

Democratizing Programming

"Digital fluency" should mean designing, creating, and remixing, not just browsing, chatting, and interacting.

BY MITCHEL RESNICK, JOHN MALONEY, ANDRÉS MONROY-HERNÁNDEZ, NATALIE RUSK, EVELYN EASTMOND, KAREN BRENNAN, AMON MILLNER, ERIC ROSENBAUM, JAY SILVER, BRIAN SILVERMAN, AND YASMIN KAFAI

Scratch: Programming for All

CACM, Nov. 2009

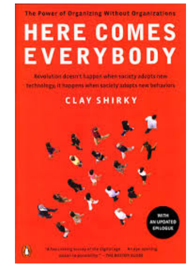
Democratizing Programming

MIT App Inventor mission statement:
The MIT App Inventor project seeks to **democratize** software development by empowering all people, especially young people, to transition from being consumers of technology to becoming creators of mobile technology.

Clay Shirky on Situated Software vs. Web School (2004)

Target small population

- NYU ITP *Teachers on the Run* vs. RateMyProfessors.com
- scaling issues unimportant
- simple hardwired data vs. scalable databases
- software for your mom

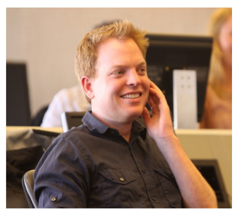


Leverage small groups

- local knowledge
- trust of other users
- publicly shame deadbeats in group purchase apps

http://shirky.com/writings/herecomeseverybody/situated_software.html

No Texting While Driving App



Daniel Finnegan, English Major, developed the app in Dave Wolber's USF course *CS017: Computing, Mobile Apps, and the Web*

Clive Thompson on Coding for the Masses
By Clive Thompson | November 29, 2010 | 12:00 pm | Wired December 2010

Illustration: Alex Nabaum

How do you stop people from texting while driving? Last spring, Daniel Finnegan had an idea. He realized that one of the reasons people type messages while they're in the car is that they don't want to be rude—they want to respond quickly so friends don't think they're being ignored.

So what if the phone knew you were driving—and responded on its own?

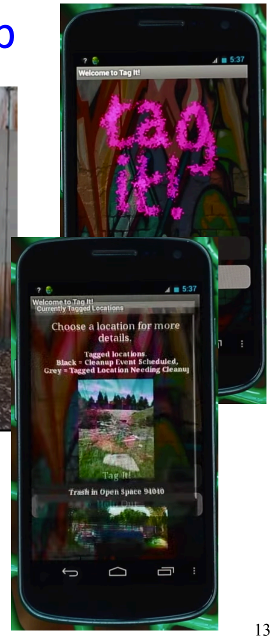
Normally, Finnegan wouldn't have been able to do anything with his insight. He was a creative-writing major at the University of San Francisco, not a programmer. But he'd enrolled in a class where students were learning to use Google's App Inventor, a tool that makes it pretty easy to hack together simple applications for Android phones by fitting bits of code together like Lego bricks.

App To Track Feral Hogs

Alabama's Lawrence County High School students used App Inventor to build an app that tracks feral hogs, which were causing economic damage to their community. Their app won a prize of $100K in technology for Samsung's 2012 Solve for Tomorrow contest.

http://www.forbes.com/sites/samsung/2013/11/25/high-school-students-battle-wild-hogs-with-stem-solutions/

Trash & Graffiti Cleanup App



East Palo Alto girls created an app to tag the location of trash and create an event for cleaning it up. This app ranked highly in the Technovation Challenge competition.

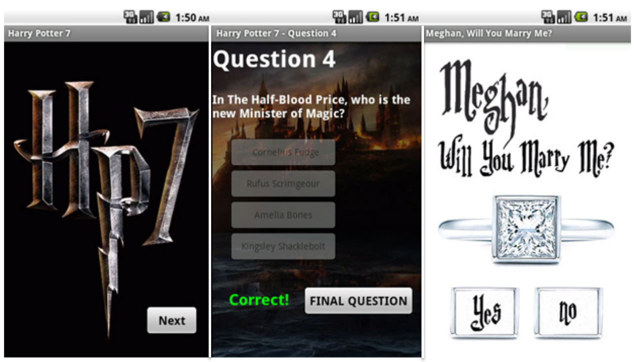
http://appinventor.mit.edu/explore/stories/east-palo-alto-girls-create-app-clean-graffiti-trash.html

App to Destroy Mines Safely

Chris Metzger, United States Marine Corps Staff Sergeant, used App Inventor to create an app that helps other Marines destroy weaponry captured in the field. It calculates the amount of explosives necessary to safely destroy captured ammunition and mines.

http://appinventor.mit.edu/explore/stories/united-states-marines-use-app-inventor-field.html

Marriage Proposal App



Hodgson didn't know how to develop an Android app. … "How the heck was I going to build this thing?" he recalls thinking. "I tried a couple of other rapid development tools, but they really had too much of a learning curve to let me do it in the time-frame I had in mind." That is, until a friend recommended **App Inventor**, a tool for amateur Android devs created by Google Labs. "It **allowed me, with no java knowledge, to quickly get this thing whipped up**," Hodgson says.

http://www.fastcompany.com/1754193/google-love-story-man-builds-android-app-propose-girlfriend

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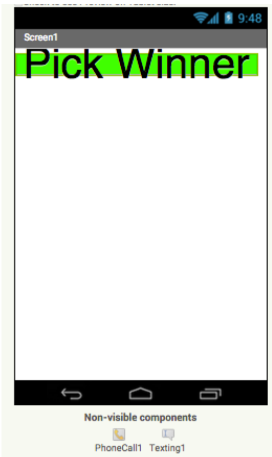
Example: Raffle App In App Inventor

http://ai2.appinventor.mit.edu

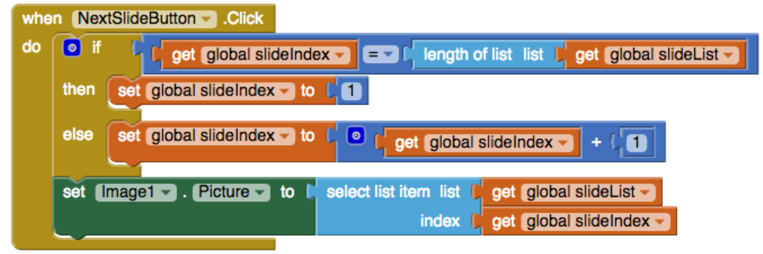
Designer Window

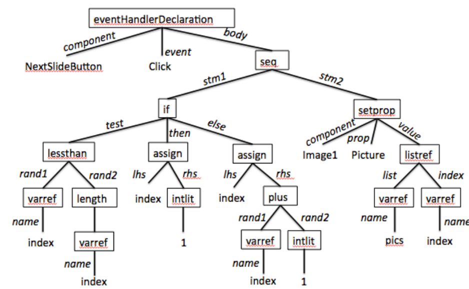


Blocks Editor

To enter the raffle, text me now with an empty message: **339-225-0287**

Blocks Represent Abstract Syntax Trees (ASTs)





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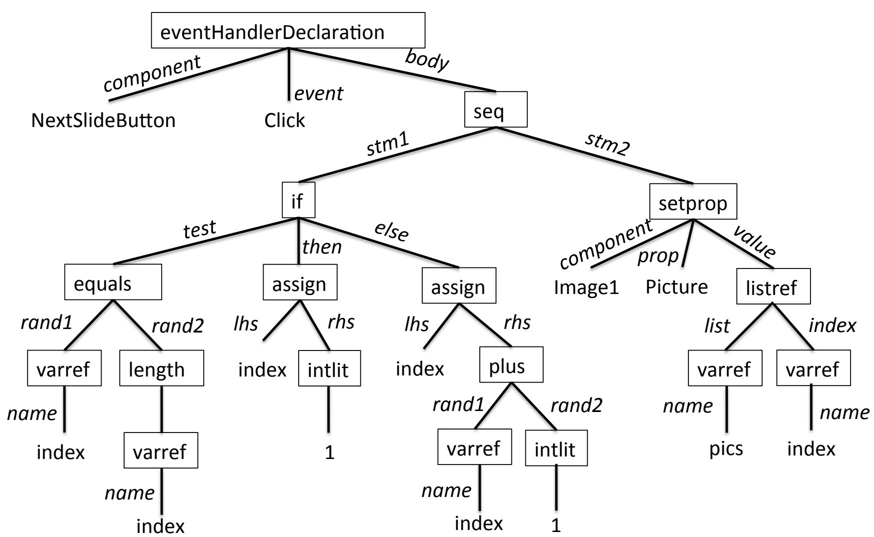
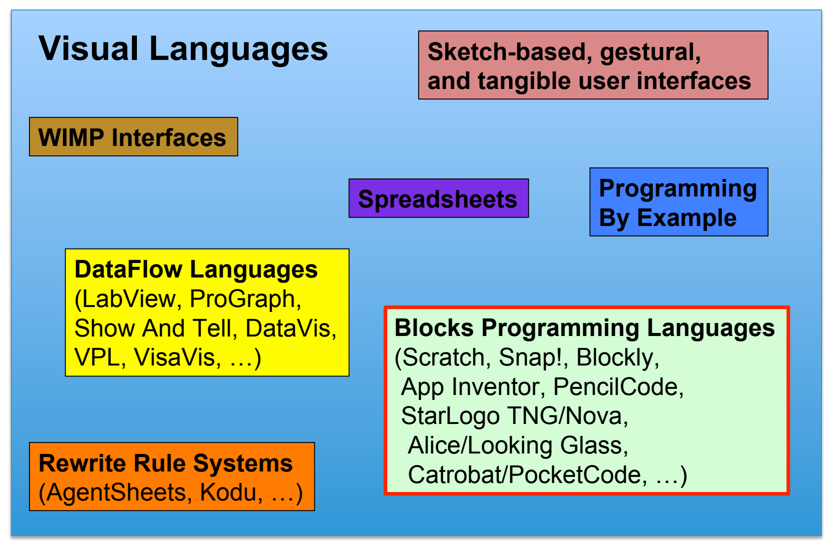
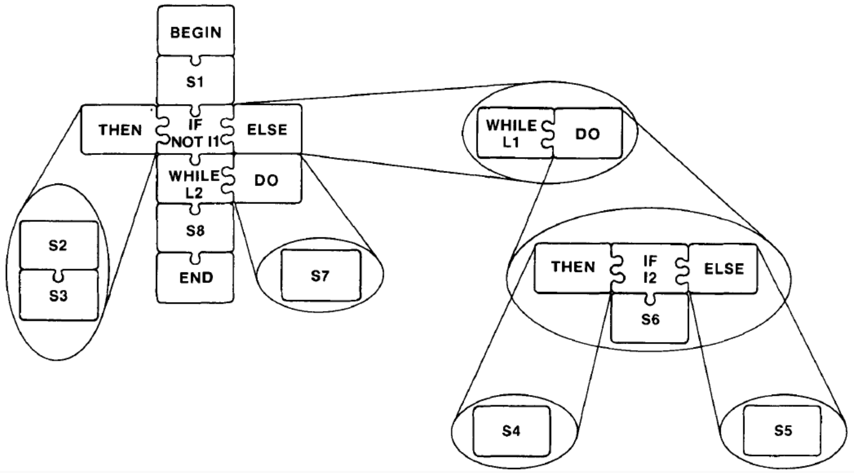


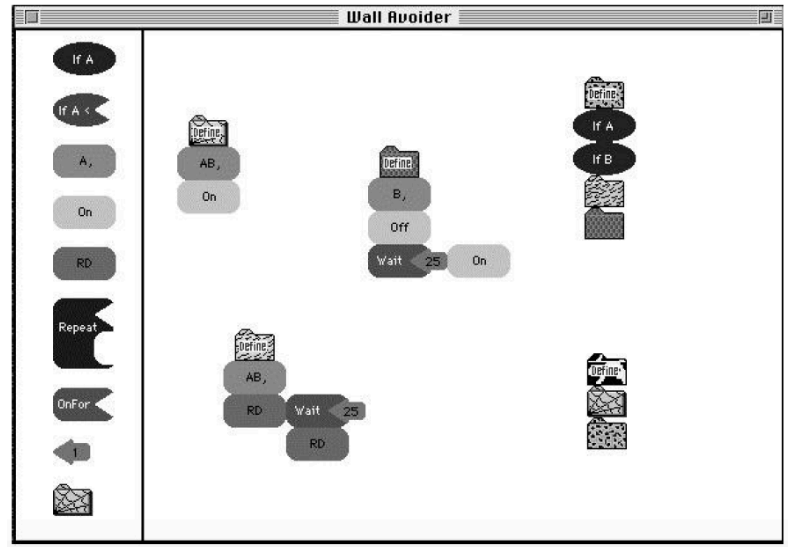
Blocks Languages in the Visual Languages Space



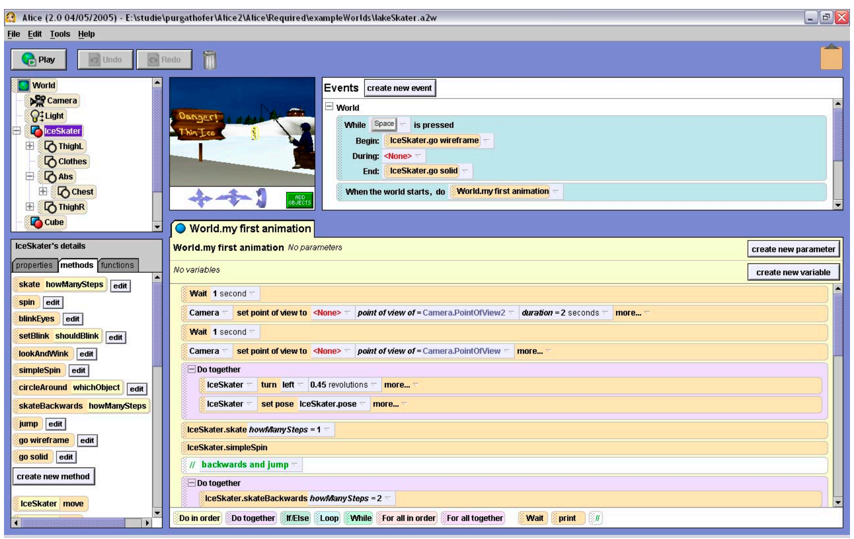
BLOX (Glinert, 1986)



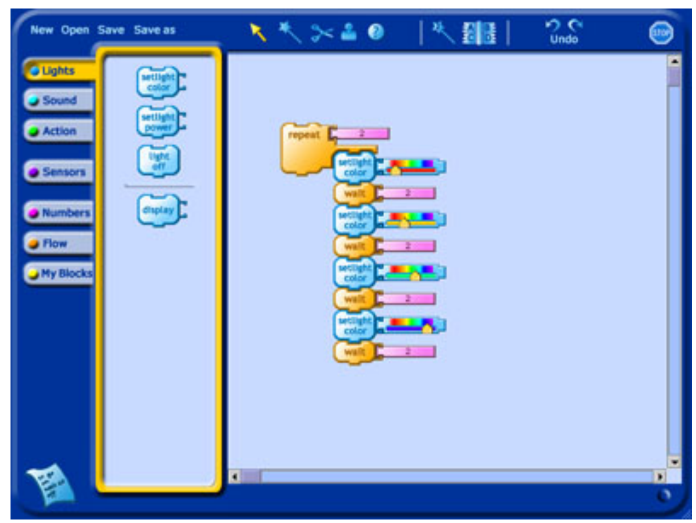
LogoBlocks (Begel, 1996)



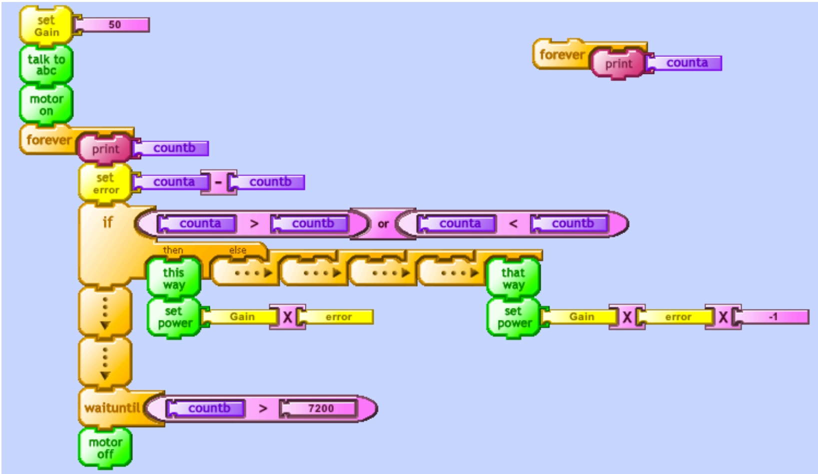
Alice (Pausch et al., 2001)



PicoBlocks (Bonta, Silverman, et al., 2006)

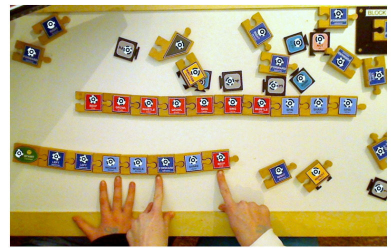


PicoBlocks Passes the "Lucite Test"



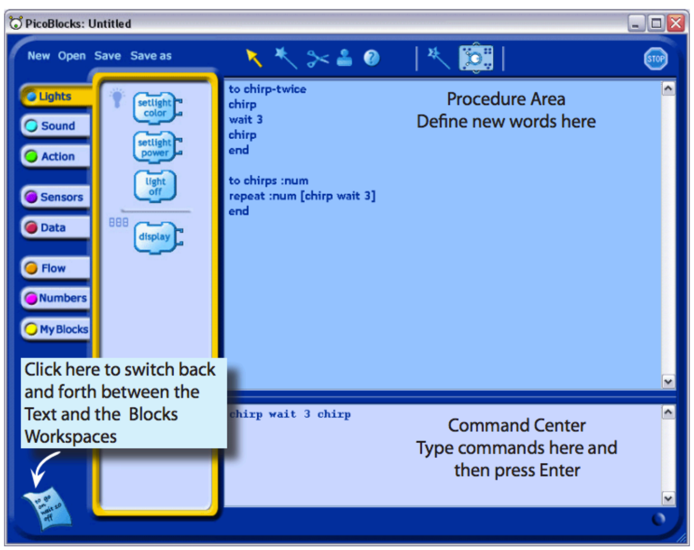
Languages with Physical Blocks

Robot Park (Horn, Solovey, & Jacob, 2007)



Tangible Kindergarten (Bers and Horn, 2009)

PicoBlocks Text/Extension Language



Scratch (Resnick et al., 2007)

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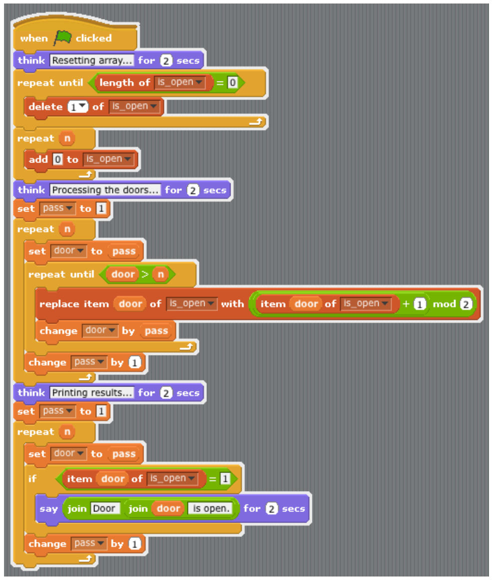

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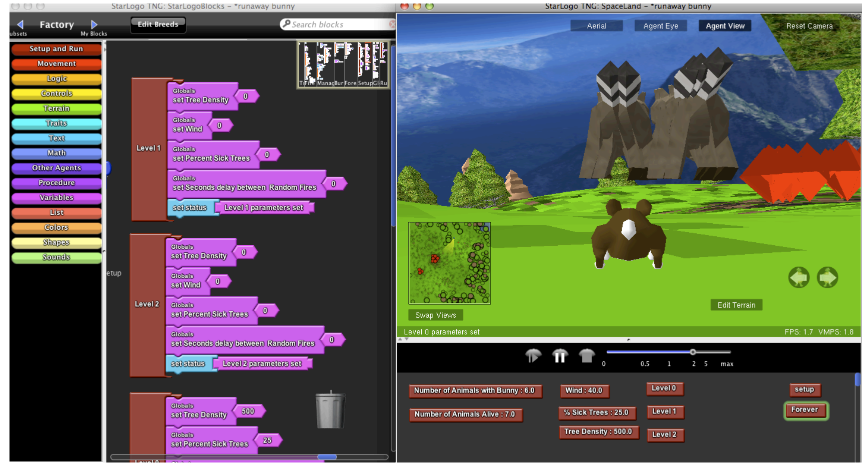
StarLogo TNG (Roque, Wendel, et al., 2007)



- Different plug shapes for different expression types: number, boolean, string, list
- Source of the OpenBlocks Java-based blocks framework

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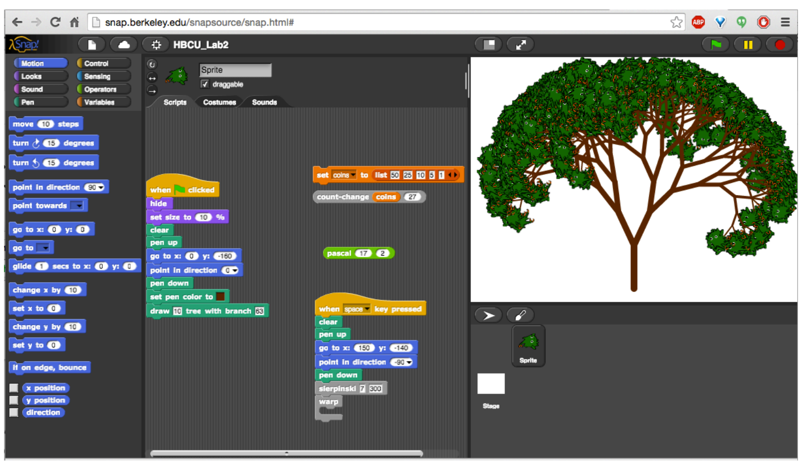
BYOB/Snap! (Harvey, Moenig, et al., starting 2008)



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BYOB/Snap! Have First-class Functions

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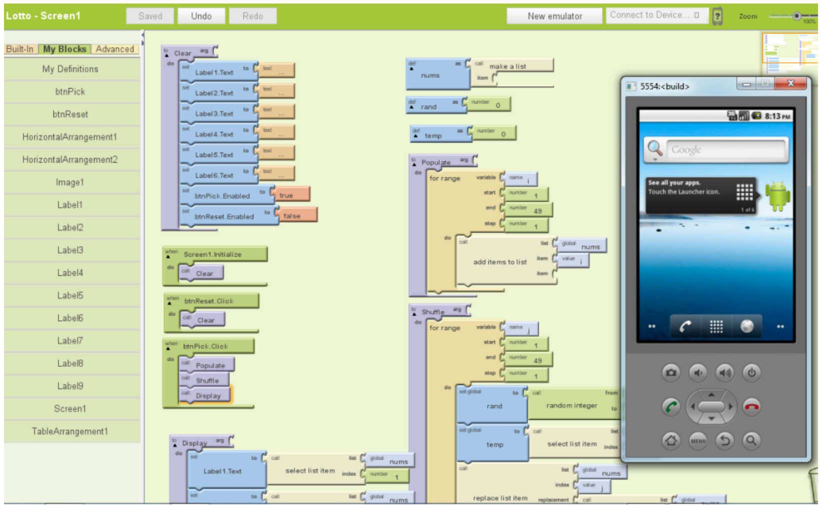
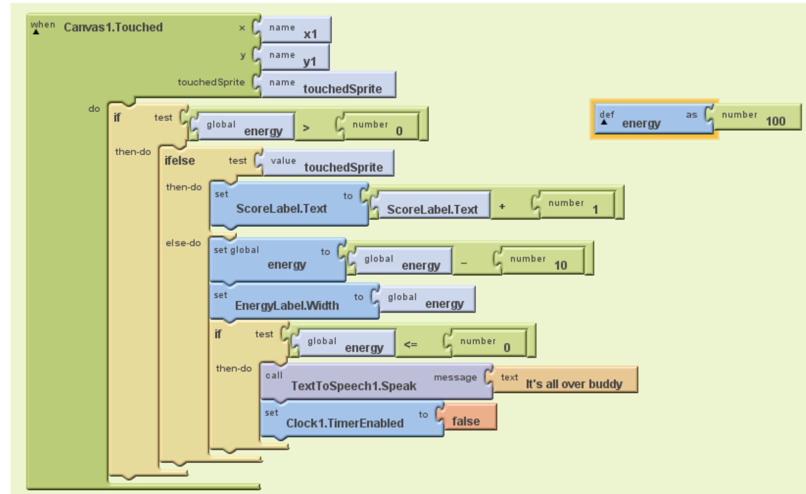
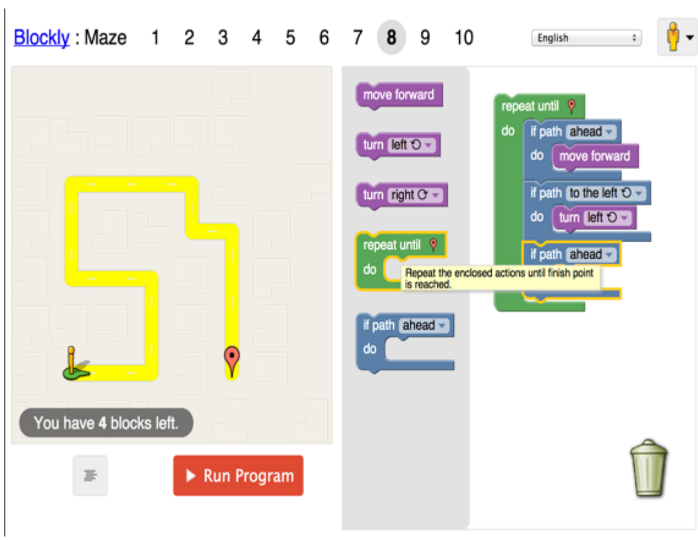
App Inventor Classic (Abelson et al., 2009)



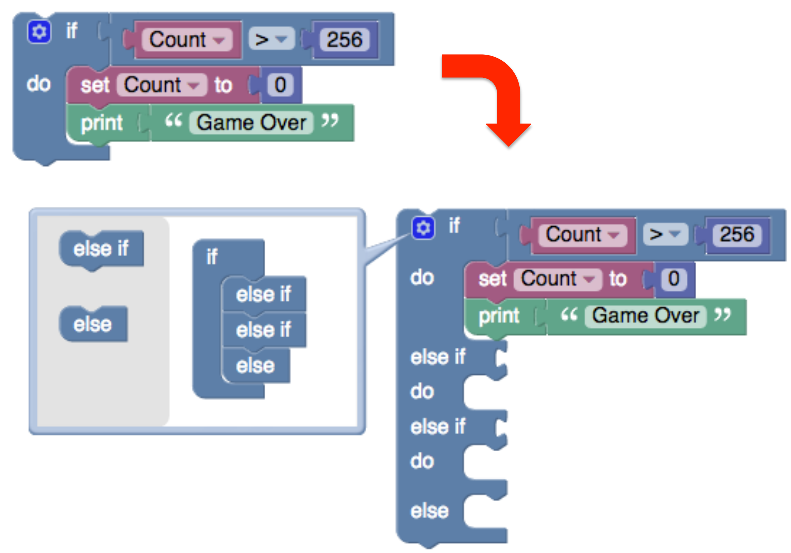
App Inventor Classic Blocks



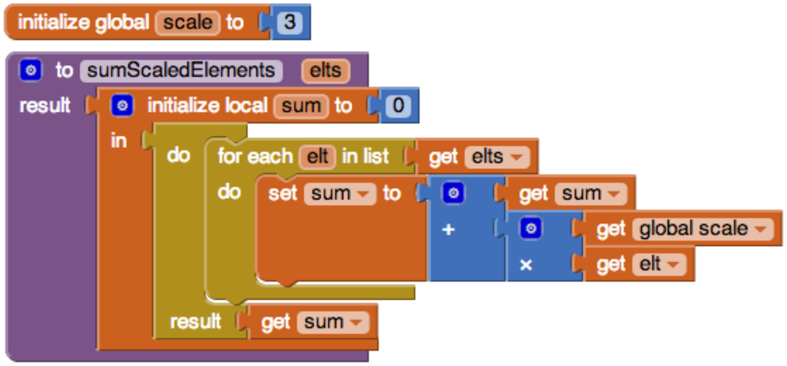
Blockly (Fraser, 2012)



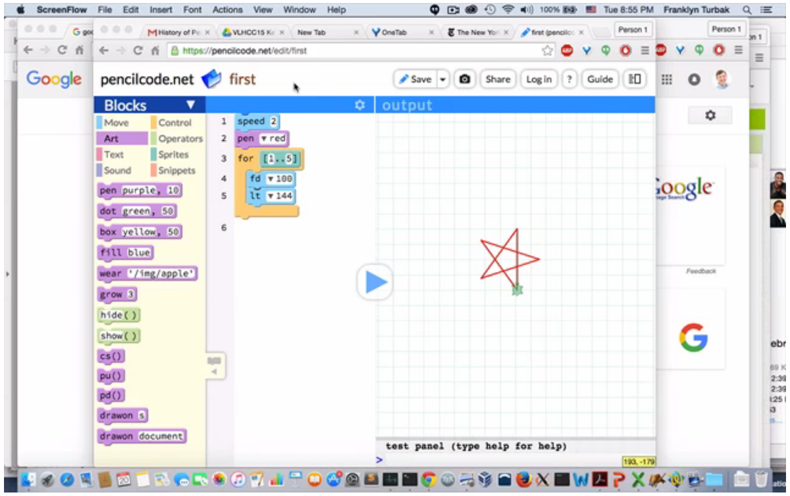
Blockly Mutators



MIT App Inventor 2 (2013)



PencilCode (D. Bau 2013), Droplet (D.A. Bau, 2014)



Code.org Hour of Code (launched Dec. 2013)

By Feb. 2014:
- 26.5 million participants
- 74% used a blocks language (Code.org Blockly exercises, Scratch, Tynker, Hopscotch, App Inventor, Alice, Looking Glass)
- 17% used a traditional text language (e.g., JavaScript, Python)

As of now: claim 133 million participants

Blocks Languages are Exploding in Popularity!

8M registered users
11.1M projects shared
58M comments posted
120K monthly active project creators

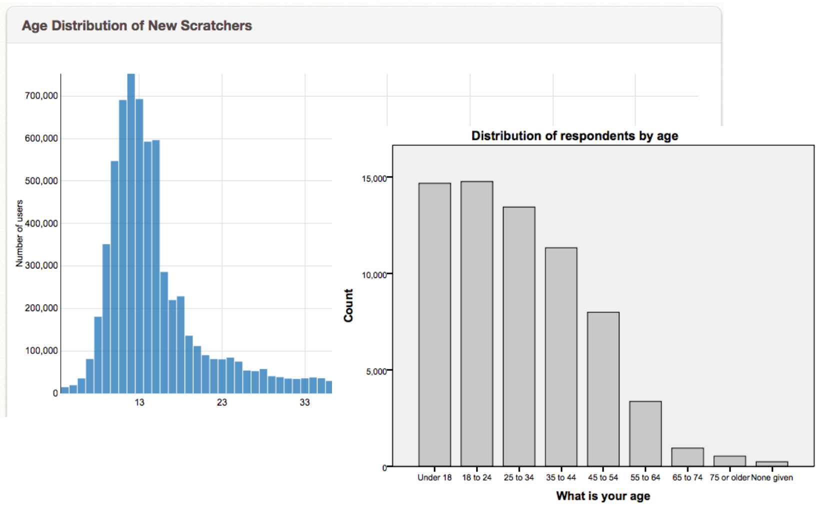
3.8M registered users
195 countries
10.8M mobile apps created
138K weekly active users

MIT App Inventor

Snap!

348K projects by 52K users
In Sep 2015, 62.7K projects updated by 10.5K distinct users
BJC used in ~125 schools

Age Distribution: Scratch vs. App Inventor



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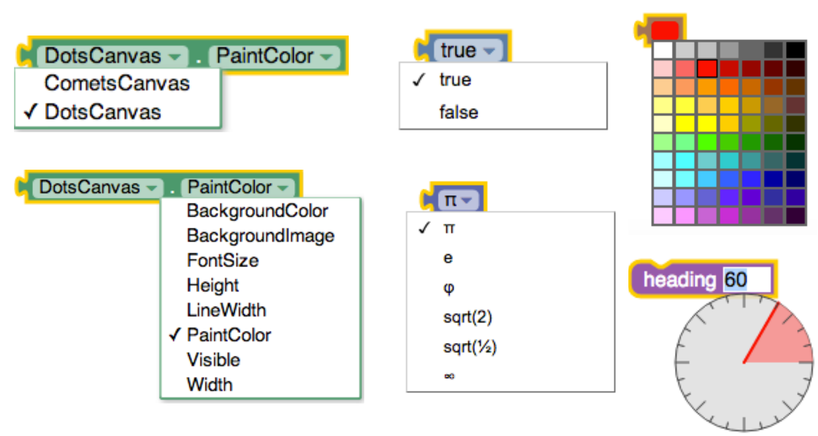
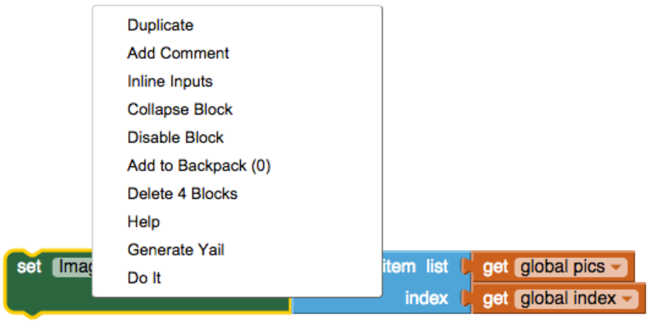
Lowering Barriers: Syntax

- Needn't worry about character-level details and errors (punctuation, capitalization, etc.)
- Recognition from menu of blocks is easier than recall.
- Blocks can have extra annotations to clarify meaning and document sockets.
- Block shapes distinguish expressions, statements, and declarations, preventing fundamental syntax errors.
- Nesting highlights procedure/loop bodies, conditional branches, and scope regions.
- Can move, copy, delete entire syntactically meaningful units.
- Blocks structure emphasizes tree-based nature of programs.

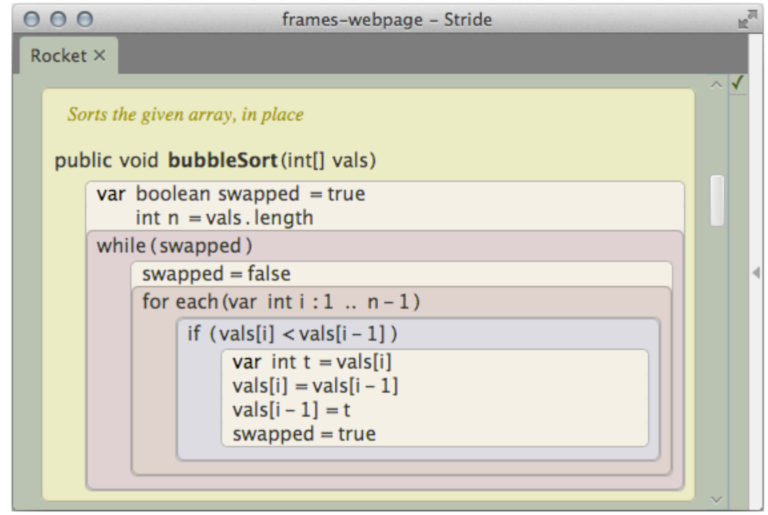
Drop-Downs & Special Editors Reduce Errors & Viscosity



Blocks can be Hooks for Other Operations



Greenfoot's Frame-based Editing



Some Research Questions

1. What are the most beneficial affordances of blocks language syntax? Which of these should be incorporated into IDEs for text-based language

2. Can we improve line-based debuggers by focusing on syntax nodes instead?

```
var z = g(x) + f(g(y))
```

3. Distinguishing grammatical phrase types:
   - How important is it for blocks representations to distinguish expressions, statements, and declarations?
   - Are distinctions based on plug/socket shape/orientation more effective than others (color, positioning, nesting, etc.)?
   - Are some shapes/orientations of plugs/sockets more effective than others?

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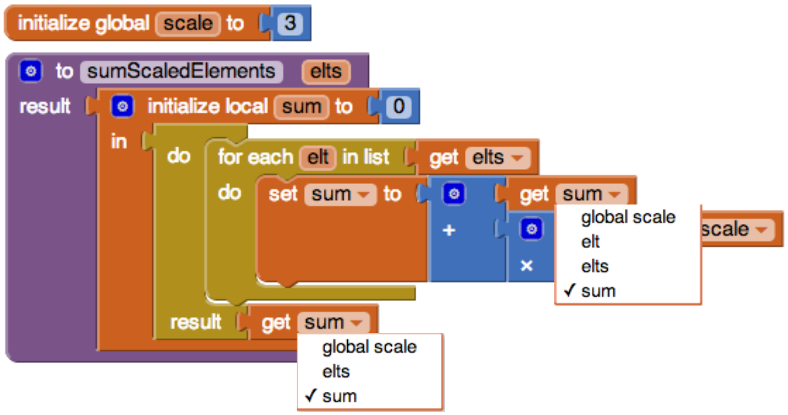
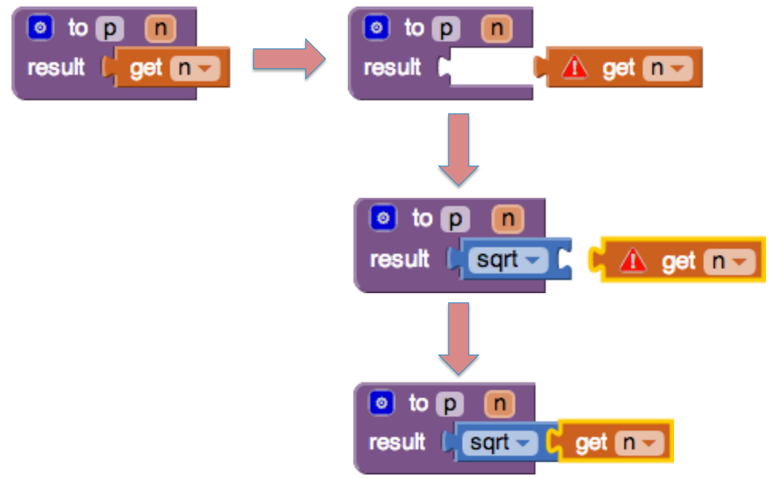
Static Semantics: Name Scoping in AI

- Globals are in a separate namespace
- Indentation visually highlights area of name scope
- Drop-downs list only names in scope.
- Inner names can shadow outer ones
- Changing declared names automatically consistently changes all references

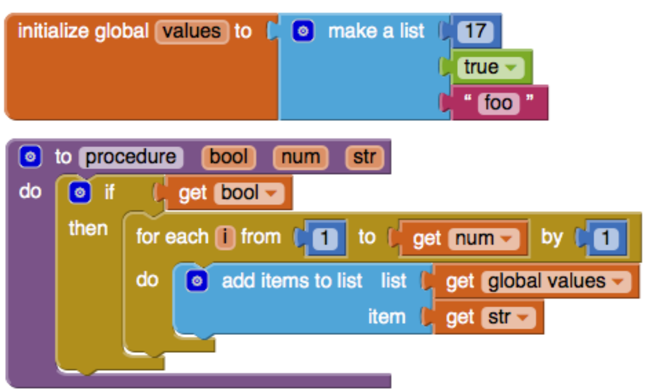


Handling Unbound Names



Static Semantics: What About Types?

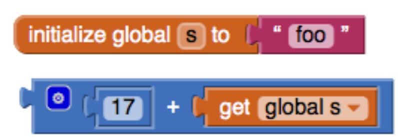
App Inventor is dynamically typed, so there's only one plug shape:



Simple "Soft" Static Type Checking in AI

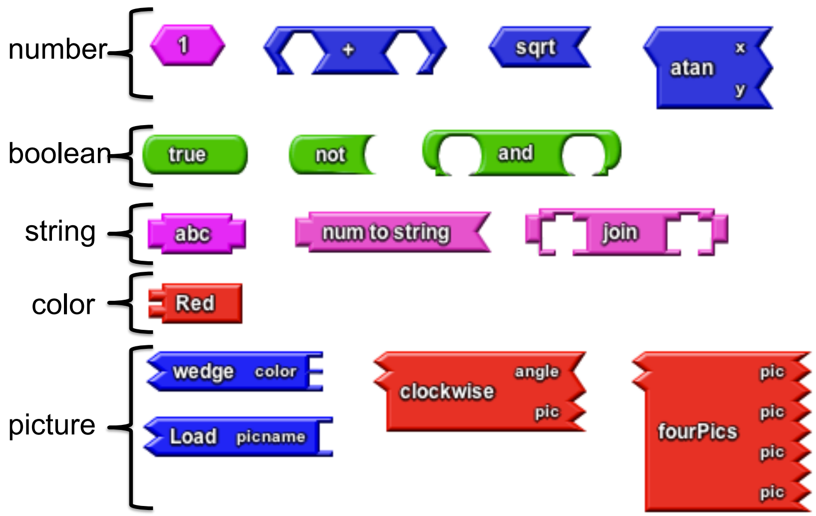
Type errors at block connection time are prohibited by "repulsion"

Dynamic type errors can be hidden by variables:

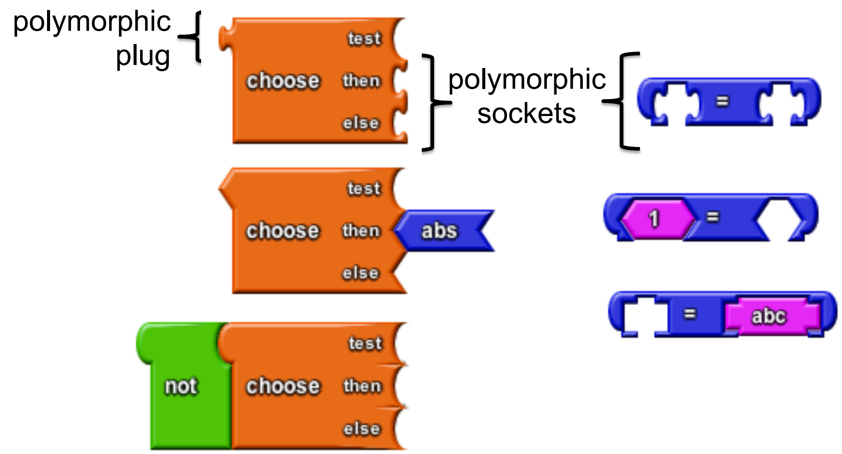


Connector Shapes in Wellesley PictureBlocks

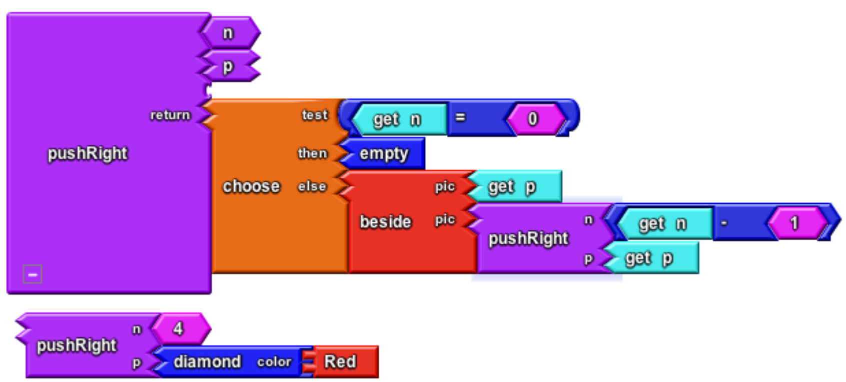
(Inspired by types-as-shapes in StarLogo TNG)



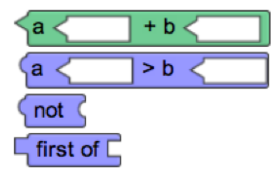
Polymorphism in PictureBlocks

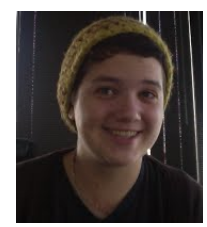


pushRight: Complete Declaration and Call

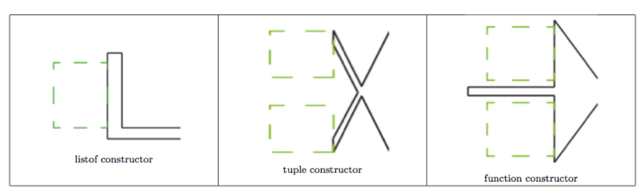


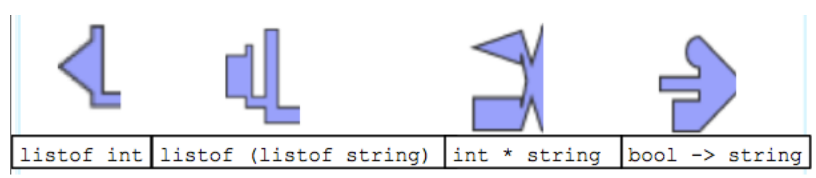
Type Blocks



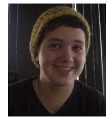


Marie Vasek '12
Wellesley



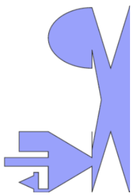


Type Blocks: More Examples



`listof (string * boolean)`

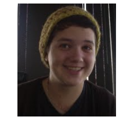
`(listof string) * boolean`

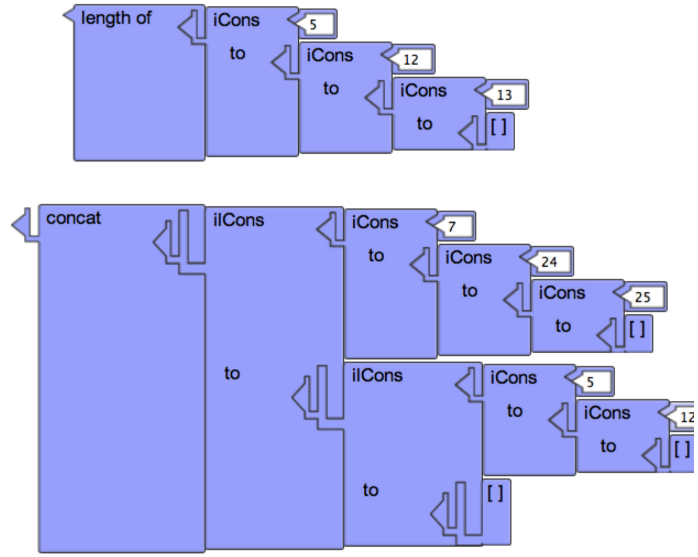


`boolean * (string -> listof number)`

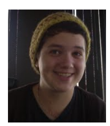
`(boolean * string) -> (listof number)`

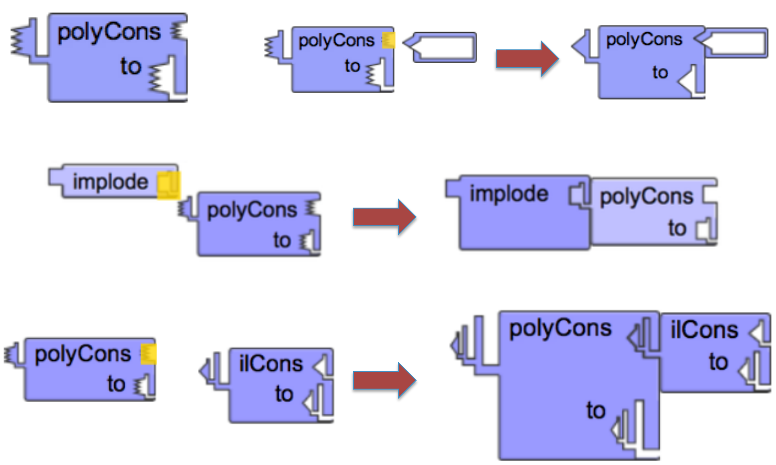
Type Blocks: Lists





Type Blocks: ML Style Universal Polymorphism





Some Research Questions

1. Are plug/sockets shapes that distinguish expression types (e.g., in StartLogo TNG, PictureBlocks) beneficial?
2. How understandable are various approaches to expressing sophisticated types and polymorphism visually ?
3. For statically typed language L (e.g. C, Java, ML, Haskell), can we design a blocks system for L that accurately and understandably represents types visually?

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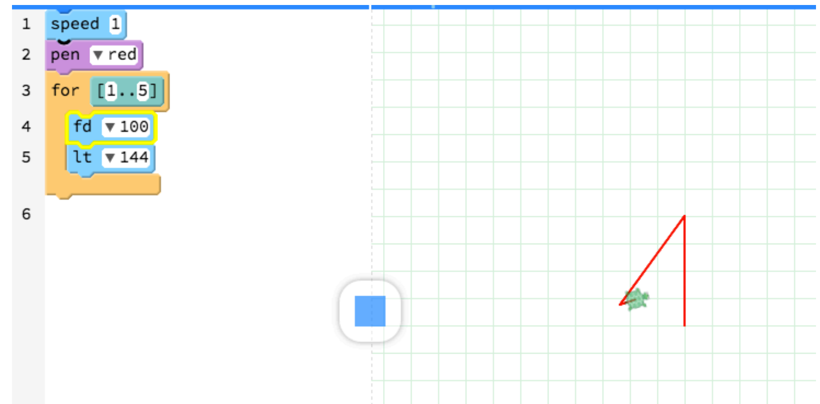
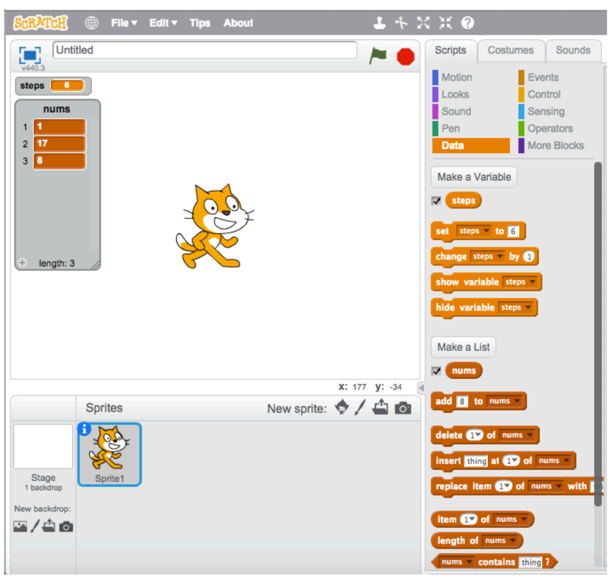
Stepping in PencilCode, early Scratch

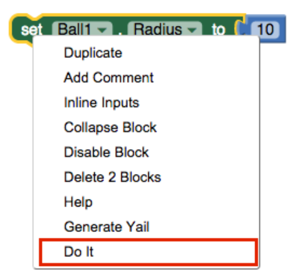


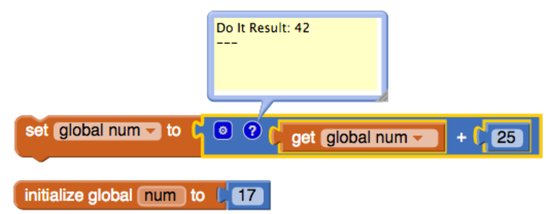
Variable Display in Scratch



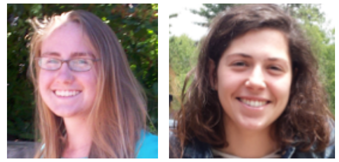
App Inventor: DoIt

Simple form of interactivity/liveness found in many blocks environments (as well as interpreter text-based languages).



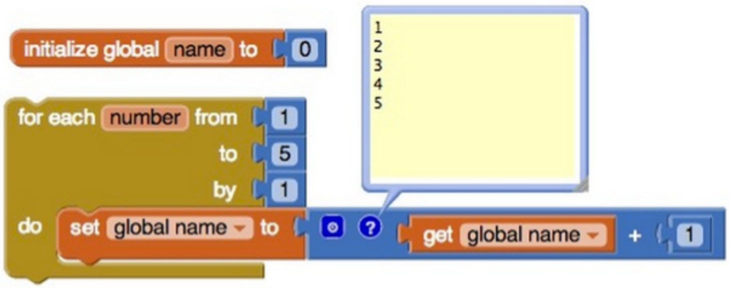


Better Debugging: Watch



Johanna Okerlund '14 Wellesley

Emery Gerndt Otopalik '16 Wellesley



Some Research Questions

1. What are better ways to show the execution of blocks programs? How to handle the visualization of function calls and complex data?

2. What information is most useful for helping blocks programmers debug typical errors?

3. What to do in cases (robotics, mobile apps) in which the program is running on a device other than the computer in which it's been written?

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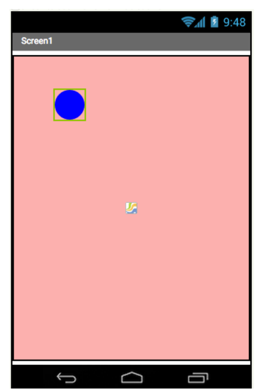
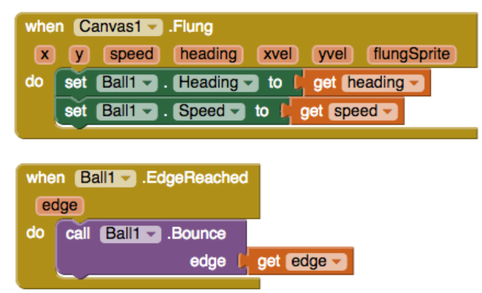
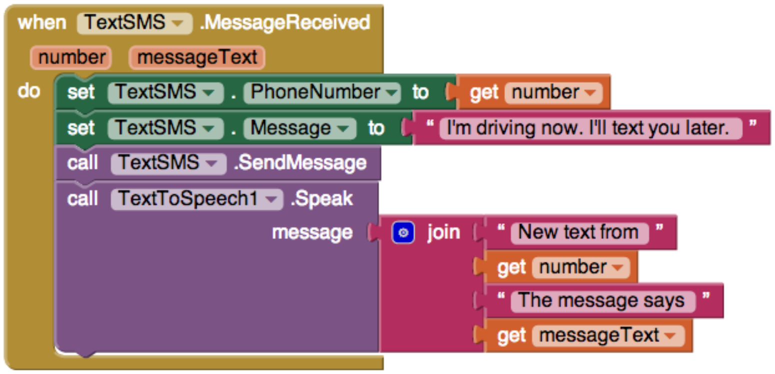
Thinking Outside the Blocks: Abstraction





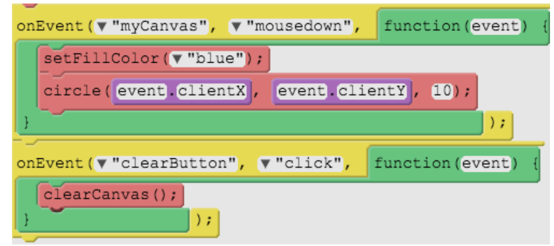
Thinking Outside the Blocks: Abstraction

What does this code do?

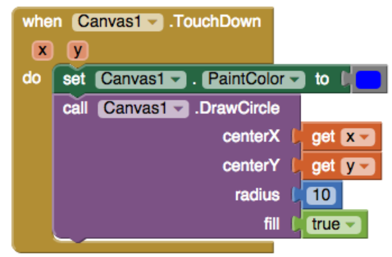


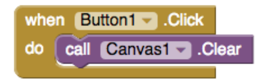
Thinking Outside the Blocks: Abstraction

App Lab/ Droplet

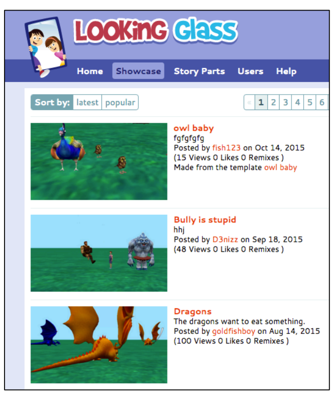


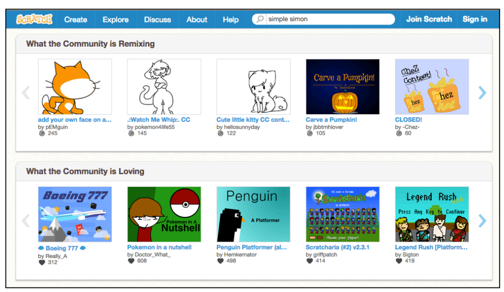
App Inventor

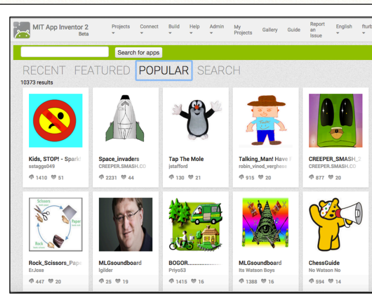




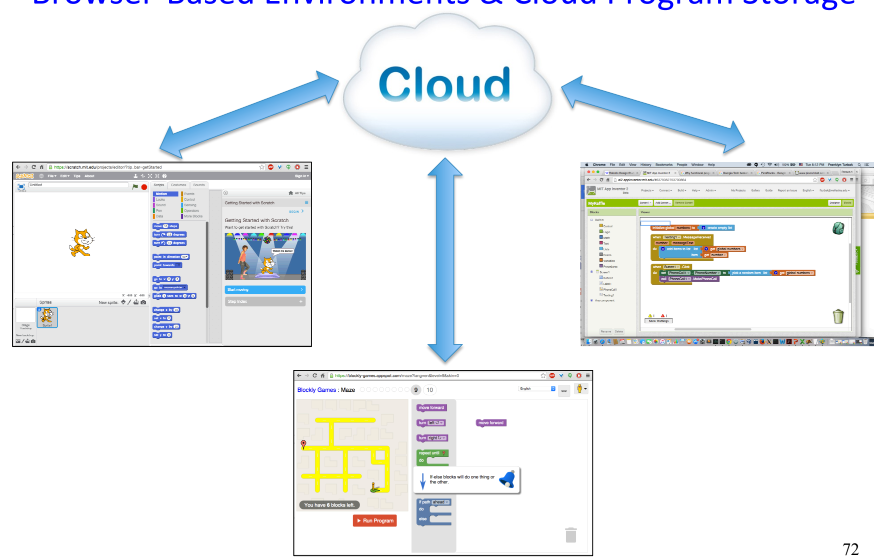
Thinking Outside the Blocks: Community







Thinking Outside the Blocks: Browser-Based Environments & Cloud Program Storage



Some Research Questions

1. Which programming abstractions developed in blocks languages are worthwhile to incorporate into traditional languages.
2. Can we learn something from sharing/remixing communities in blocks languages that we're not learning from communities (e.g. forums) for other languages?
3. What kinds of analysis can be done on the massive cloud data collected for user blocks programs to better understand their learning, help them to debug their programs, and improve the programming environments they use?

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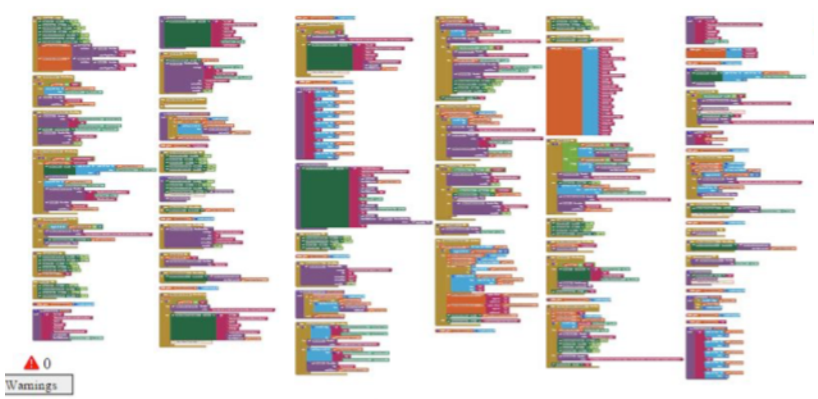
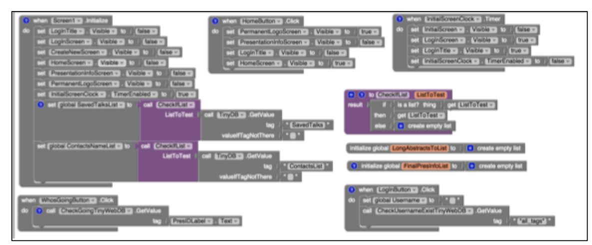
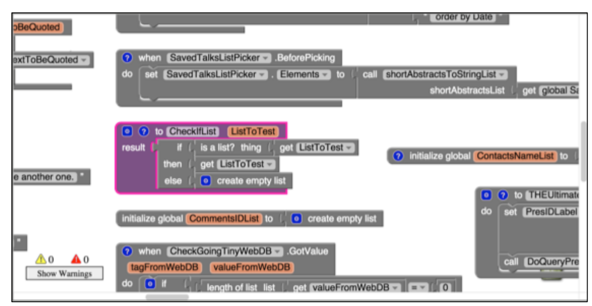
Usability: Big Programs are Hard to Understand



Usability: Searching 2D Blocks Workspaces





Cece Tsui '18
Wellesley

Usability: Organizing 2D Blocks Workspaces

Shirley X. Lu '15
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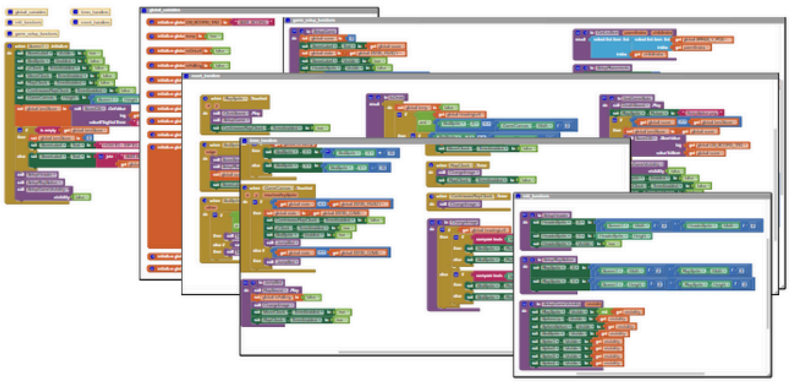
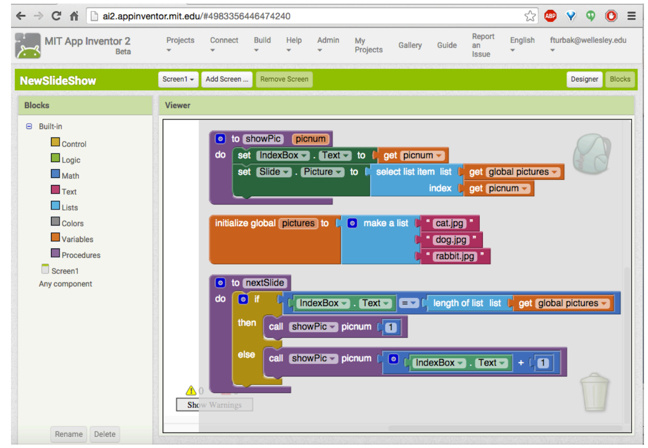
Devid Farinelli '16
U. of Bologna

Folders in App Inventor (under development)



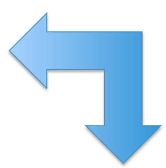
Usability: Reusing & Sharing Blocks Programs

Backpack in Scratch and App Inventor



Usability: Droplet's Isomorphic Blocks/Text Conversion

Used in PencilCode and Code.org's AppLab JavaScript curriculum

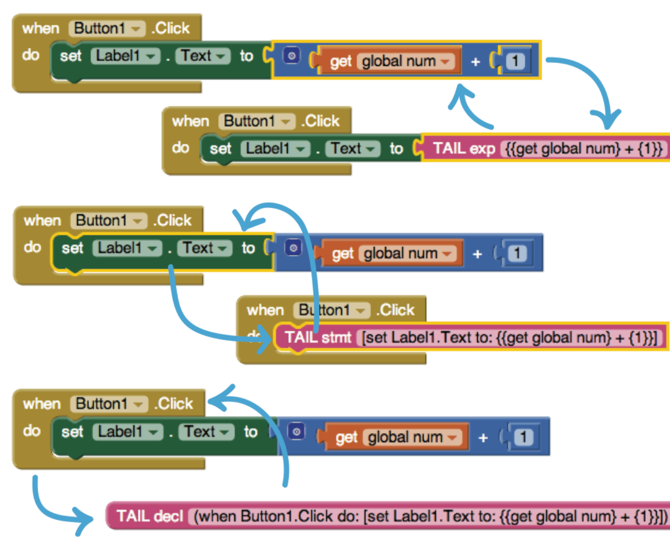


```
onEvent("dropdown1", "change", function(event) {
  if (getText("dropdown1")=="Lady Gaga") {
    setImageURL("id", "http://code.org/images/logo.png");

  } else {
    setImageURL("id", "http://code.org/images/logo.png");

  }
});
```


AI: Conversion Between Blocks and Text



Karishma Chadha '14
Wellesley

Some Research Questions

1. Which aspects of 2D blocks layout are beneficial and which are not?
2. What are effective ways to create, organize, search, and navigate 2D blocks programs? Can we do these on small screens?
3. What are effective ways to leverage the best aspects of blocks and text when creating and manipulating programs?
4. What tools can better support the collaborative construction of blocks programs? (Neil Fraser and Mark Friedman at Google have done preliminary work on a kind of Google Docs for Blocks.)
5. How can we improve accessibility of blocks programming environments for the blind and visually impaired?

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Learnability in Blocks vs. Text

- Lewis: Logo vs. Scratch study (SIGCSE 2010)
  - Few significant differences between Logo-first and Scratch-first
  - Scratch-first did better on conditionals
  - Logo-first had more confidence as programmers.
- Meerbaum-Salant, Armoni, & Ben-Ari (ITiCSE 2011)
  Scratch programmers have undesirable "habits of programming": bottom-up programming & extremely fine-grained programming
- Weintrop and Wilensky: Snap! vs Java (IDC 2015)
  - Blocks easier to read and compose than text
  - Blocks perceived as more verbose, less powerful, less authentic
- Problem: Nonisomorphic languages
  - Weintrop and Wilensky Commutative Assessment on blocks vs. text in isomorphic languages (ICER 2015) is promising approach
  - Matsuzaka taught Java with blocks environment isomorphic to text (SIGCSE 2015). Students perceived text as more "real".

Some Research Questions

1. Do Matsuzaka's results hold in other examples in which blocks and text language are very similar or isomorphic? Tools like Droplet should make this easier.
2. If people transition from a blocks language to a more traditional text language, what concepts and skills are transferred? What difficulties are encountered? What kinds of explicit instruction can aid this transfer?
3. Are there particular transition paths from blocks languages to traditional languages that tend to have better conceptt and skill transfer than others?

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Negative Responses to Blocks Languages

I have never met a student who cut their teeth in any of these languages and did not come away profoundly damaged and unable to cope.

I mean this reads to me very similarly to teaching someone to be a carpenter by starting them off with plastic toy tools and telling them to go sculpt sand on the beach.

Not one thing they learn will bear any piece of resemblance to real work. All you're doing is teaching them misimpressions of what the job is, and tricking them out of having meaningful formative experiences.
http://blog.acthompson.net/2012/12/programming-with-blocks.html

Working with actual code writing instead of a drag & drop interface prepares children better for the real world.
http://www.playcodemonkey.com/

Mark Sherman's Response

Mark Sherman
UMass Lowell

So they currently see this:

when it is really this:

Yes, it is colorful and newfangled, but it still gets jobs done. Not all of them, but a bunch of them.

Why do they see it this way? Because they grew up on this:

More Positive Feedback

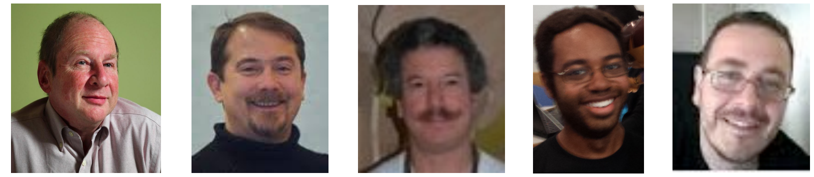
I would like to express my utmost appreciation for your product. I'm teaching several pre-CS courses for gifted youth at Junior-high school level (7th-9th grades) as well as CS and software engineering at high school (10th – 12th grades) including Android development in Java. **It is really amazing that in AppInventor, 7th grade students (with about 50 hours prior experience in Scratch) can do in 6 hours what 12th grade students take about 200-300 hours to achieve in Java (and this is after studying CS and Android development for about 700 hours).** AppInventor goes way beyond the 80:20 principle (80% of the utility in 20% of the effort) – it is more like 60:5 (60% of the functionality, for less than 5% of the effort) which makes it much more fun, and opens up a lot of space for creativity.

Yossi Yaron, Israeli teacher

Some Research Questions

1. In what substantive ways are particular blocks programming languages inferior to text languages with which they are being compared?
2. What can be done to make blocks languages appear more "real" to novice programmers?

App Inventor Development Team



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Mark Friedman Google | **Sharon Perl Google** | **Liz Looney Google** | **Neil Fraser Google (Blockly)** | **Franklyn Turbak Wellesley College**

Computational Thinking Through Mobile Computing NSF Grant Team

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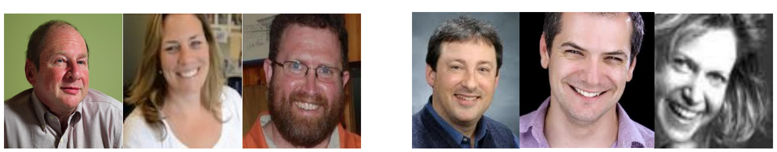
Ralph Morelli — **Trinity College**
Dave Wolber — **U. of San Francisco**
Larry Baldwin — **BIRC**



Hal Abelson, Shay Pokress, Josh Sheldon — **MIT**
Fred Martin, Mark Sherman, Karen Roehr — **University of Massachusetts Lowell**

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Wellesley TinkerBlocks Students






Questions?

Research Questions are at **http://tinyurl.com/VLHCC15Blocks**