
Microsoft® Research
Faculty Summit
10
YEAR ANNIVERSARY

Robots as a Context for Teaching Beginner Programmers:

The Conclusion of Three Years' Research at IPRE

the first!

Mark Guzdial
Professor & IPRE Lead PI
Georgia Tech

For Co-PI's
Tucker Balch (GT),
Doug Blank & Deepak Kumar (BMC)
With
Stewart Tansley (MSR)

IPRE Origins ~ MSR's perspective

Microsoft Research

- In 2003…
- Shared Computer Science (CS) attraction & retention concerns
- A rising tide of robots in Education
- Other contextualized CS education efforts emerging
- Meanwhile, PC technologies entering robotics research

- Many worthy but scattered efforts across CS1 classes
- How to make a difference?

- A major, definitive, and highly-focused research initiative:
  - ***A $1M 3-year research center***

- How to find the best team and partners to host?

IPRE Foundation ~ MSR's perspective

Microsoft Research

- We invited 8 thought-leading schools at the end of 2005
- 4 submitted full proposals

- Georgia Tech with Bryn Mawr College ~ a "dream team"
  - Diverse perspectives
  - Best in class pedagogy and robotics credentials
  - A shared vision with us
  - Excellent partners during negotiations

- **IPRE launched in Summer 2006**

IPRE Launch

Microsoft Research

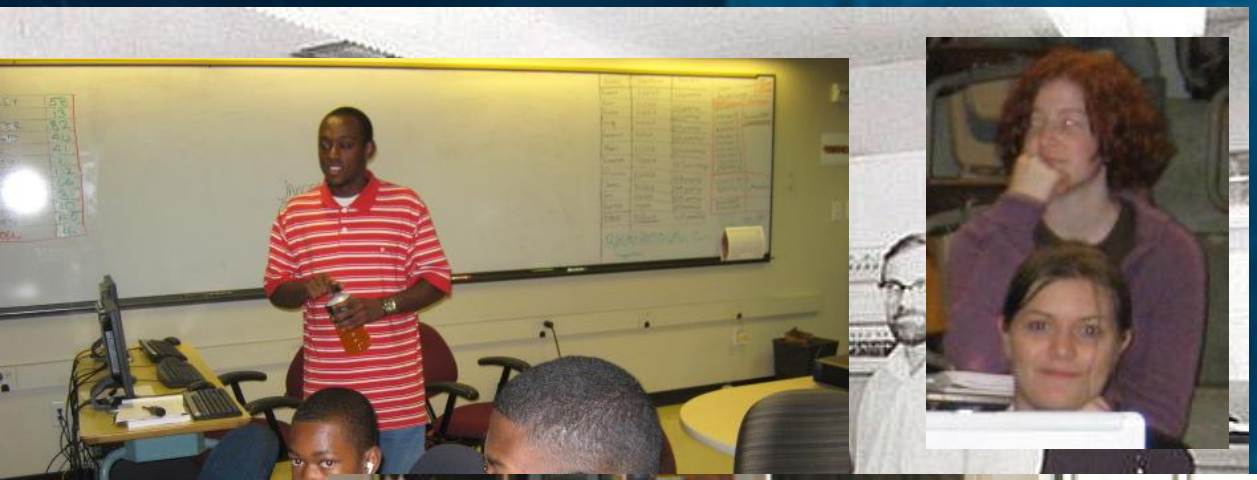
Story

Microsoft Research

- Who do we want to engage with computing? Why? And How?
- The Institute for Personal Robotics in Education: Teaching Computing in a Context.
  - Changing how we think about Computing classes, and what students do in them
  - Supporting *multiple* contexts with robots
  - IPRE leading a robotics education community
- Assessment Results
- Second Phase Plans

Who Do We Want?

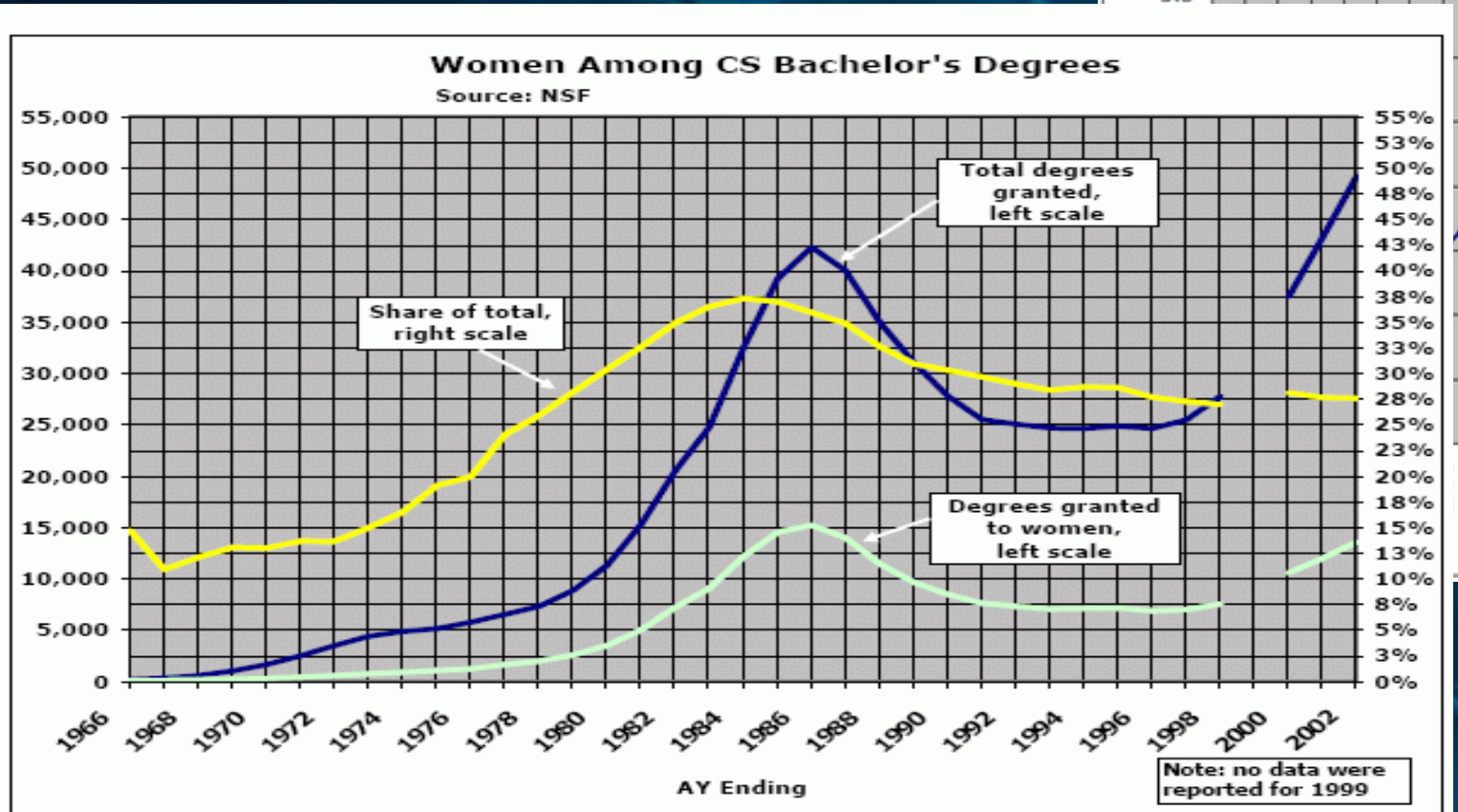
Microsoft Research

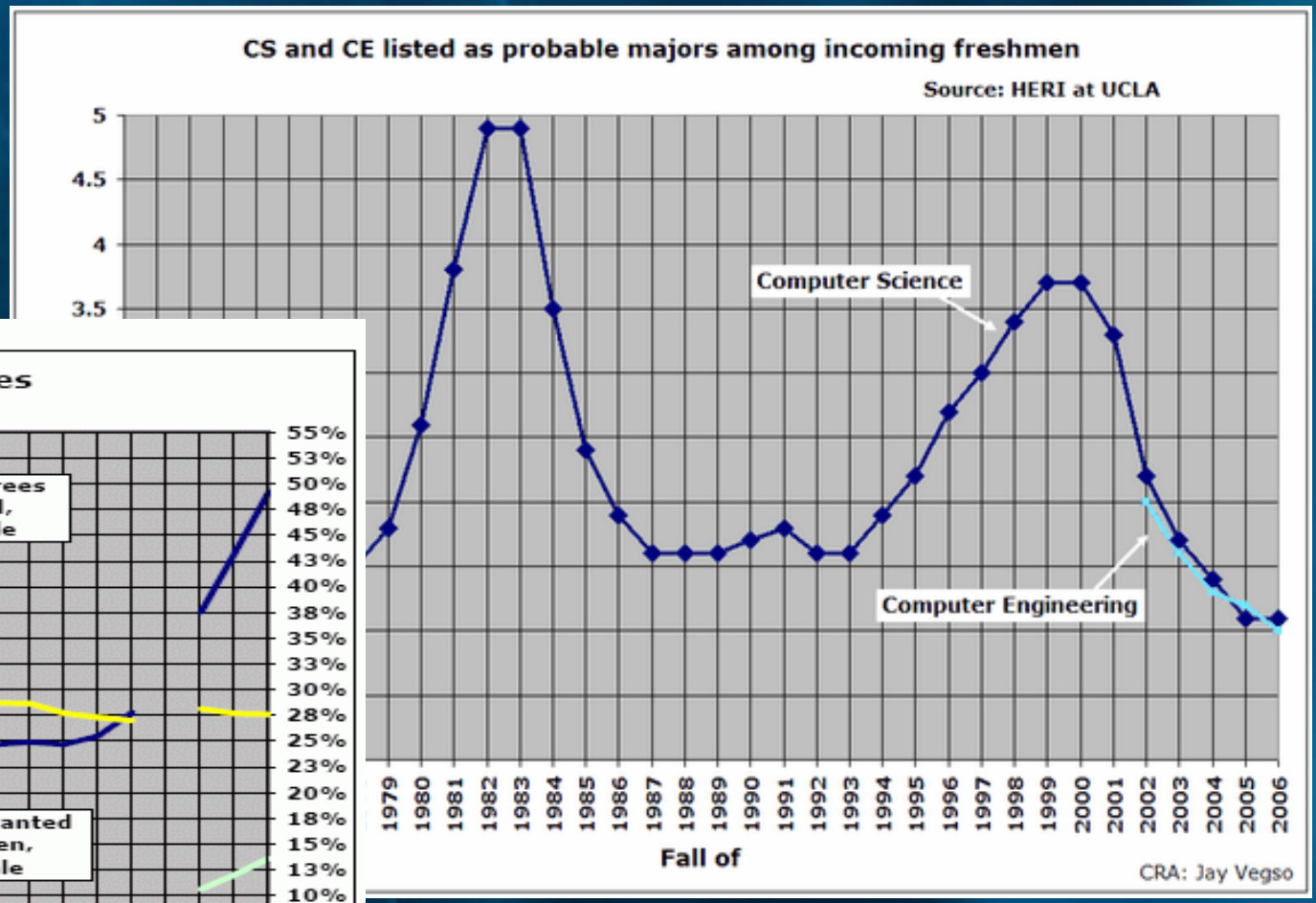


What We're Doing Is Not Working

Microsoft Research

How do we engage these students?





Why Should They Care?

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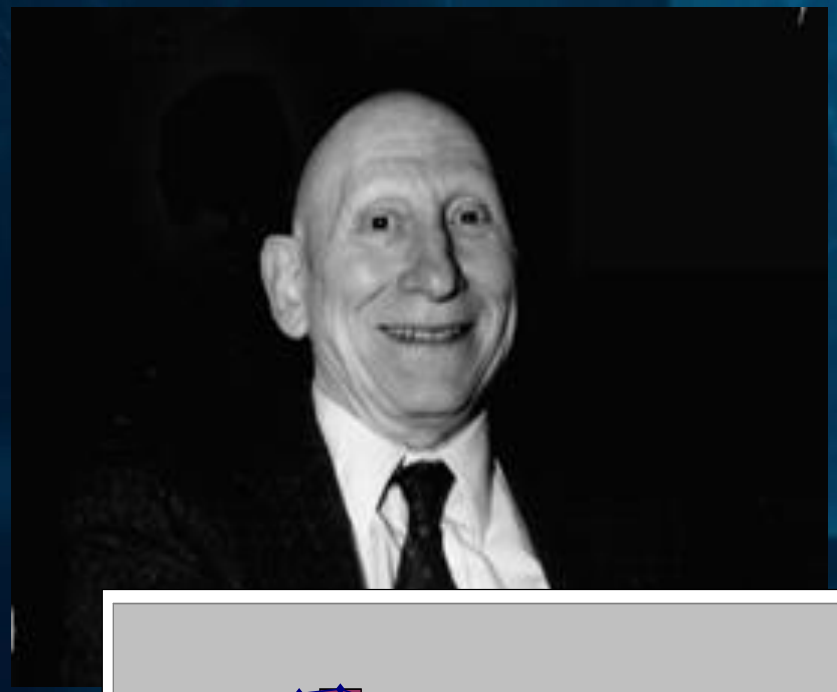
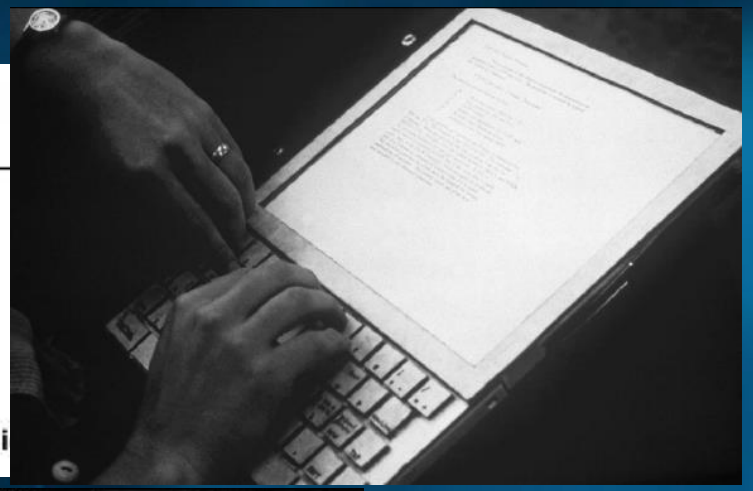


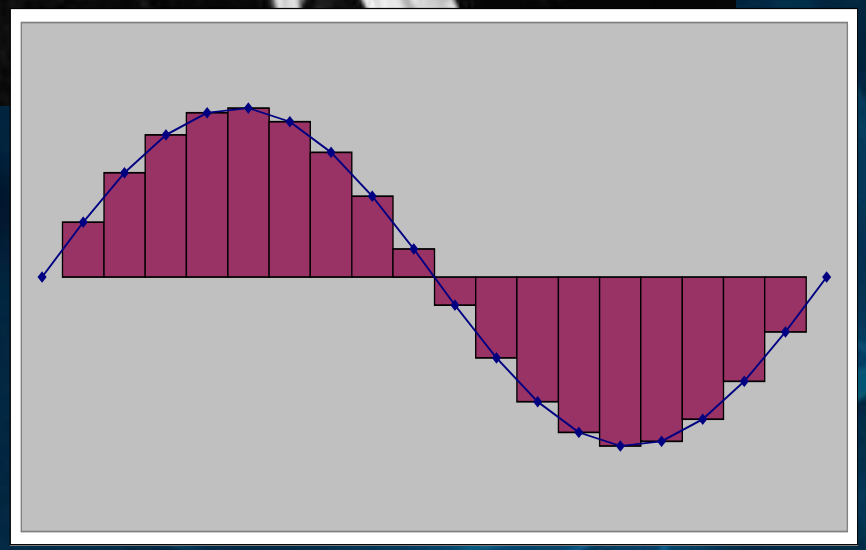
Economist.com **BUSINESS**

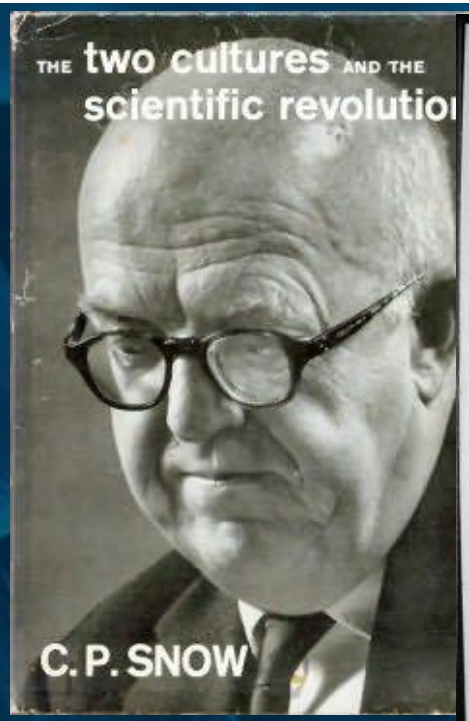
Algorithms

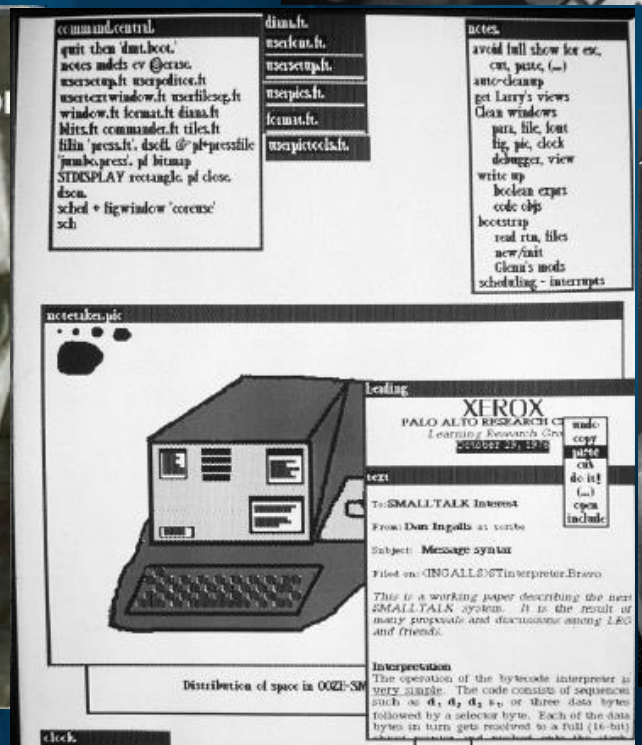
Business by numbers
Sep 13th 2007
From The Economist print edition

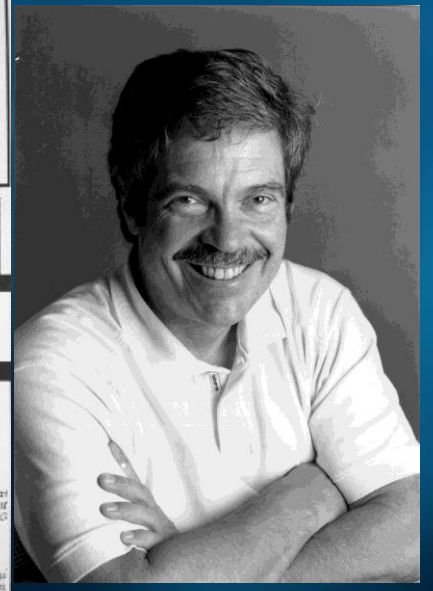
Consumers and companies increasingly depend on a hi











How Do We Teach Computing to Those Who Care About Context ?

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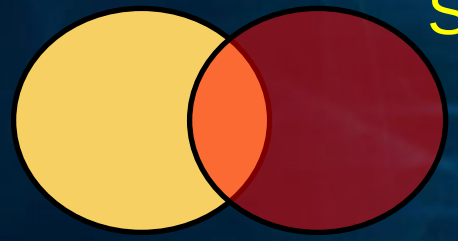
Segregationist



1. A subject that may intersect a context

Integrationist

2. A tool as seen from a context.

3. A lens that offers a new way of seeing and doing in other contexts.

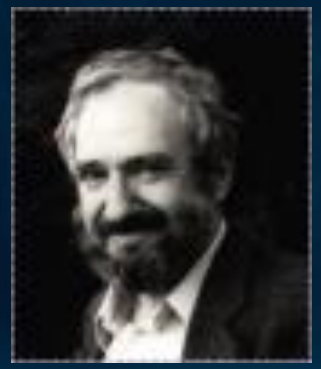
Computing as literacy

Synergist

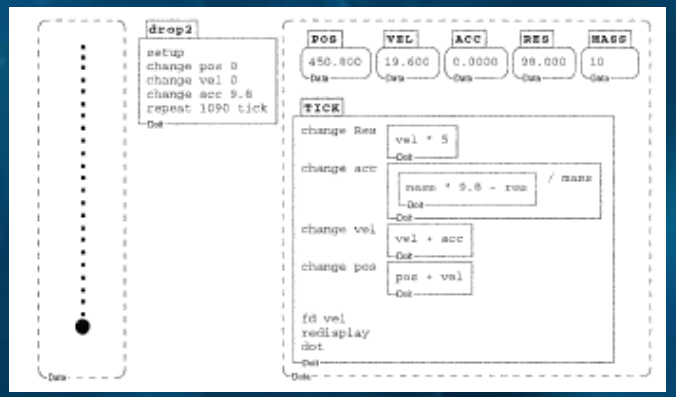
Lewis & Smith, ACM SIGCSE *inroads*, June 2005

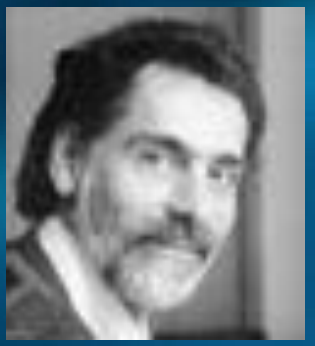
Teaching Computing as Literacy: To Help Learn Context

Microsoft Research



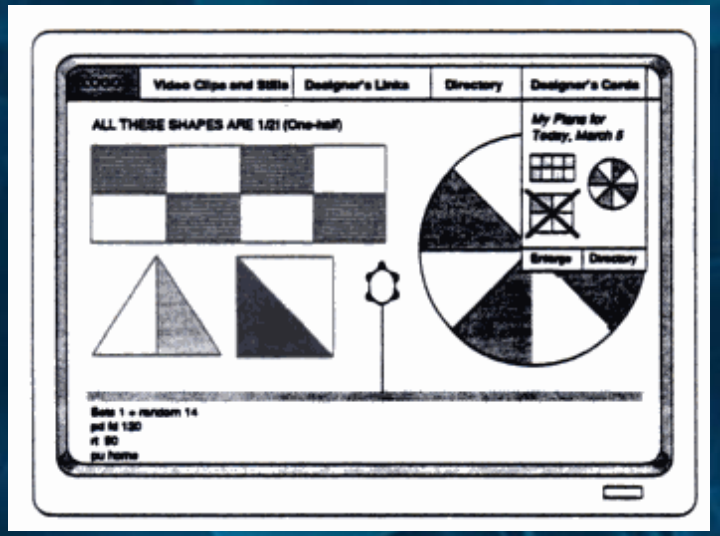
Logo





Boxer

Bruce Sherin



Idit Harel and Instructional Software Design Project (ISDP)

R = mg

Mark: That's when the forces are equal then, right?

Roger: Okay. I guess. Okay. After a certain time.

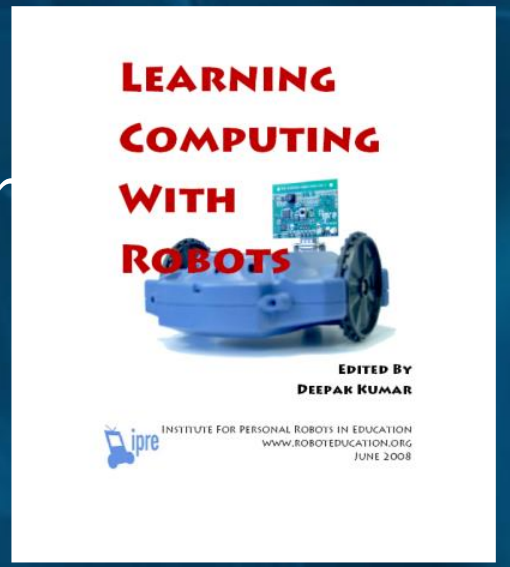
Mark: R equals G.

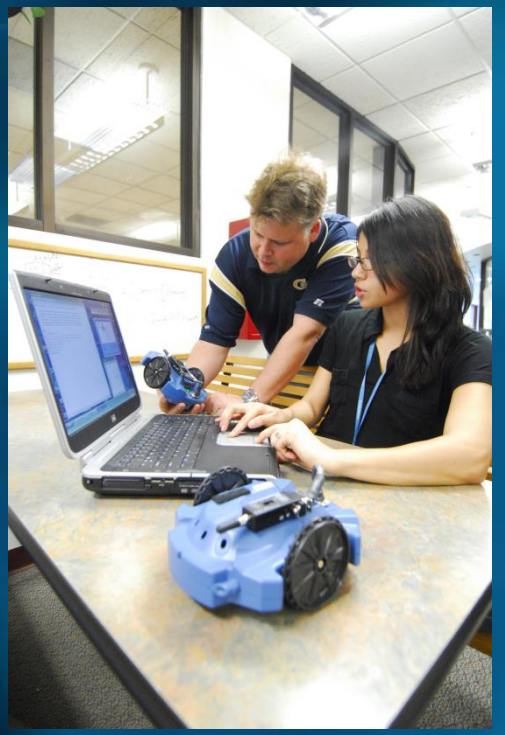
Roger: At T, some T.

Institute for Personal Robots in Education, IPRE

Microsoft Research

- **An Education Research Project**
  - Mission: Make CS education more fun ar
    effective through the context of a
    personal robot
    - A robot as a mobile media platform
  - Goal: Affect all levels, from middle
    school to graduate school
  - Initial Target: CS1
- 3-year seed funding provided by MSR
- Joint effort hosted at Georgia Tech
  with Bryn Mawr College
- **Special ingredient and hypothesis:**
  - A *personal robot* for every student





Goals of IPRE: To Do It All

Microsoft Research

History-at-a-Glance of the Project

Microsoft Research

- Year 1 (2006-2007)
  - Scribbler + Myro v1 + Book v1
  - First classes at host schools
  - First annual report published
- Year 2 (2007-2008)
  - Scribbler + Fluke + Myro v2 + Book v2
  - Award program to fund efforts at other schools
  - Workshops for teachers
  - Won award for Educational Impact at 22nd AAAI Conference
  - Second annual report flyer
- Year 3 (2008-2009)
  - Scribbler + Fluke + Myro v2.8 + Book v3 + Amazon.com
  - Using DLR and links to Microsoft Robotics Studio
  - SIGCSE 2009 Future of Robotics in Education Symposium
  - Nominated for the World Technology Awards 2009
  - Final report and documentation set to be published
  - NSF CCLI proposal

IPRE by the Numbers ~ so far…

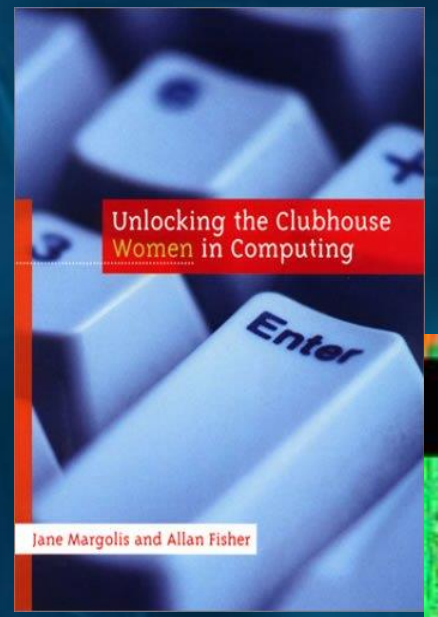
Microsoft Research

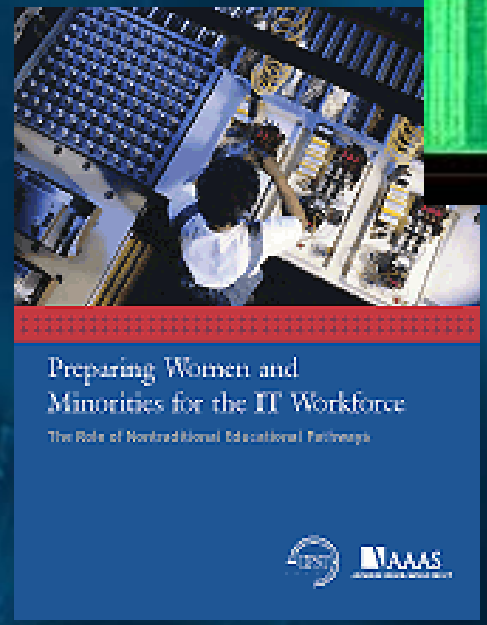
- #Students taught: 612 (BMC+GT), ~100 (Associates)
- #Schools teaching with IPRE materials: 30
- #Papers published: 10
- #Presentations made at events: 33
  - #Speakers at “Future of Robots in Education” Symposium: 29
- #LOC in Myro: 21,936
- #LOC written by beginner programmers: ~135,000
- #Programming languages available: Python, Scheme, and C++ (Myro 3: C#, Ruby, & other CLR languages)

What Happened to CS1?

Microsoft Research

- "Intro to CS" became the "**Intro to Programming**" at best, "Intro to Software Engineering" at worse
- CS became more about where to put the **curly braces** and less about the science, less about the problem solving
- Without a real problem to solve
  - CS became **less authentic**
  - CS became **less relevant**
- Irrelevancy made it **impersonal**

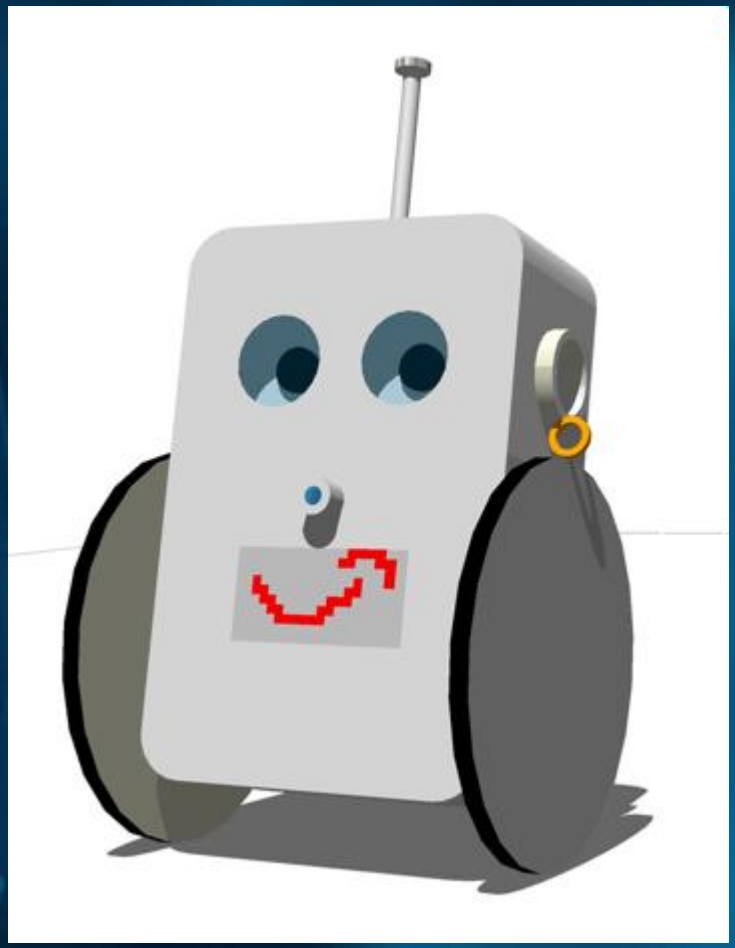




Personal Robot

Microsoft Research

- Every student gets their own robot
- Small enough to carry in backpack
- Cost about the price of a textbook
- Wireless, controlled from computer
- Interactive and easy to program
- Personalizable
- More than “just a robot”
  - A mobile media platform



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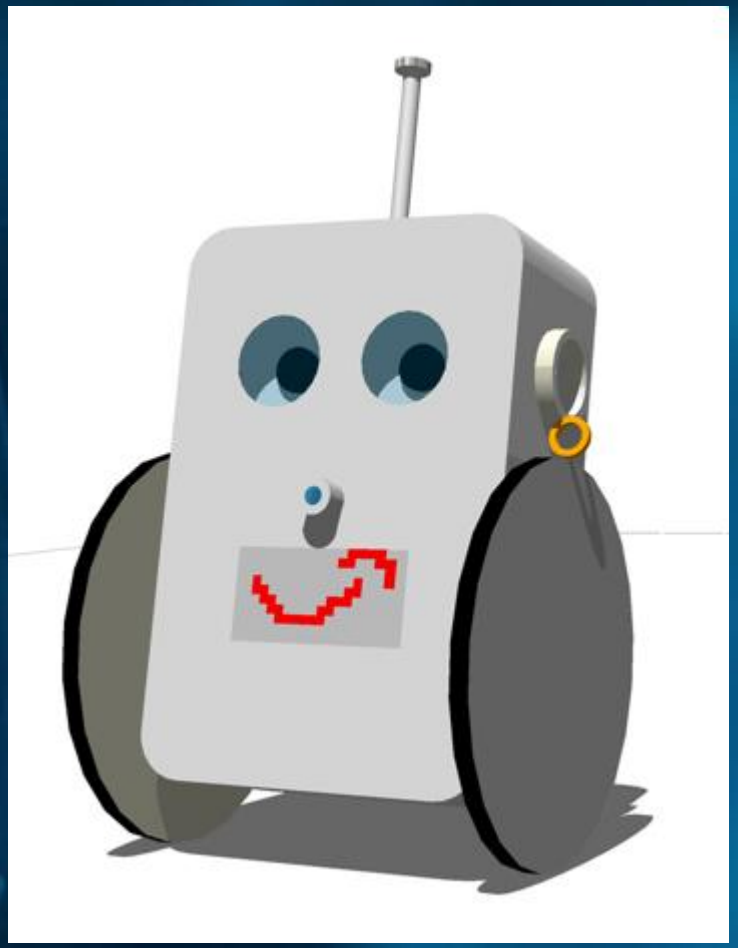
```
turnLeft(.5)
speak(“Hello, Faculty Summit!”)
playMusic(“madonna.wav”)
setFace(“smile”)
takePicture()
penDown(“red”)
```



IPRE's Philosophy

Microsoft Research

- The Personal Robot provides the *context*
- The needs of the curriculum drive the design of the robot, software, and text
- The software should be easy to pickup, but scale with experience
- An accessible, engaging environment for new, diverse students
- Computer Science != programming
- Computing a *medium for creativity*
- Focus on performances rather than competitions
- Computing as a *social activity*

IPRE Lead Institutions

Microsoft Research

- **Georgia Institute of Technology**
  - Tier 1 research university, founded in 1885
  - 15,000 students
  - Mostly male students
  - *All* students must take a course in computer science
  - Students declare their major *at time of application*
- **Bryn Mawr College**
  - Liberal arts college, founded in 1885
  - 1,200 students
  - Mostly female students
  - Few students know that CS is offered, or even know what CS is

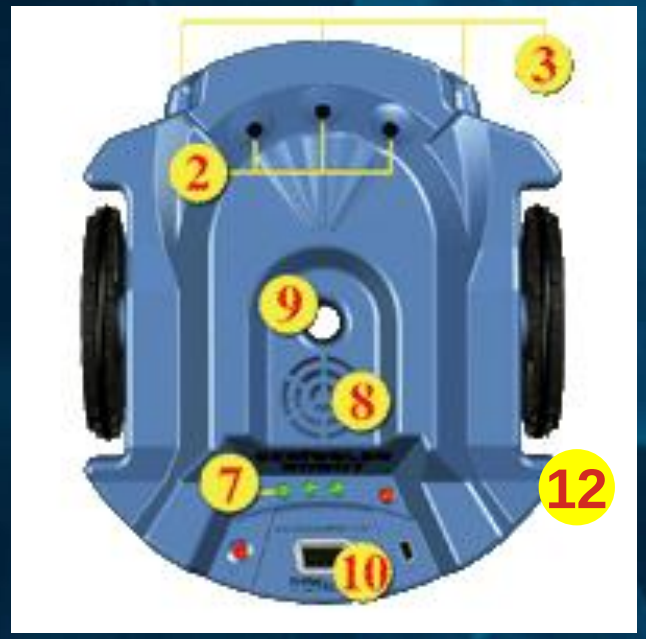
IPRE Pilot Hardware Kit Featuring Parallax's Scribbler

Microsoft Research

- 6 Light sensors
- 7 IR sensors
- Stall sensor
- Speaker
- 5 LEDs
- 2 motors
- Bluetooth wireless
- Camera
- Gamepad

Parallax Scribbler

Microsoft Research

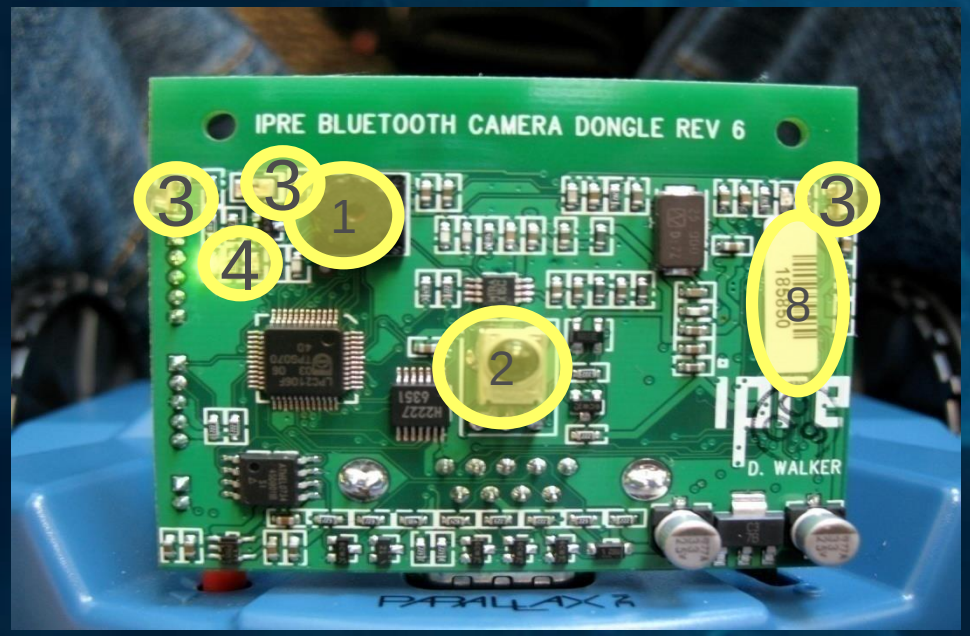


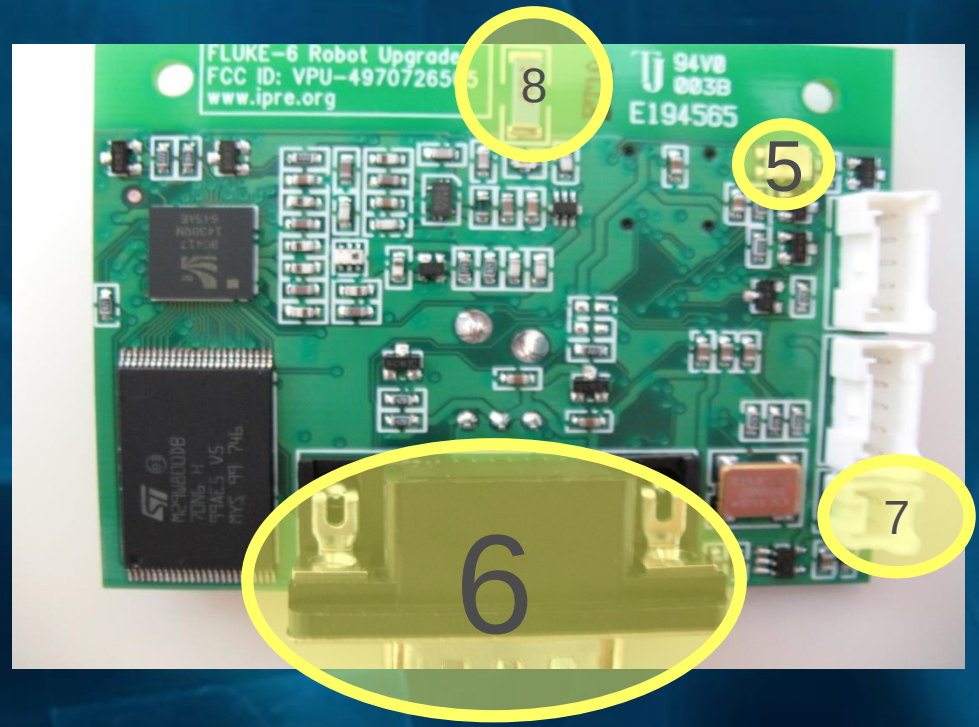
2. Left, Center, Right Light Sensors
3. Left and Right Obstacle Detectors (IR)
4. Left and Right Line Sensors (IR)
5. Left and Right DC Motors and Wheels
7. User Controlled Green LEDs

8. Speaker/Tone Generator (2 tones)
9. Marker Hole for *Scribbling*
10. Serial Port (9V on pin 8)
11. Battery Bay (6AA)
12. Blinking Low Battery Indicator

The IPRE Fluke

Microsoft Research





1. Camera
2. IR Receiver
3. IR Emitters
4. Front Green LED

5. Back Red LED
6. Scribbler Communication, Programming, Voltage Sensing
7. External Power
8. Bluetooth Antennae and Serial # (Bluetooth Name)

Wireless Robot:
1 robot, 1 laptop, 1 student

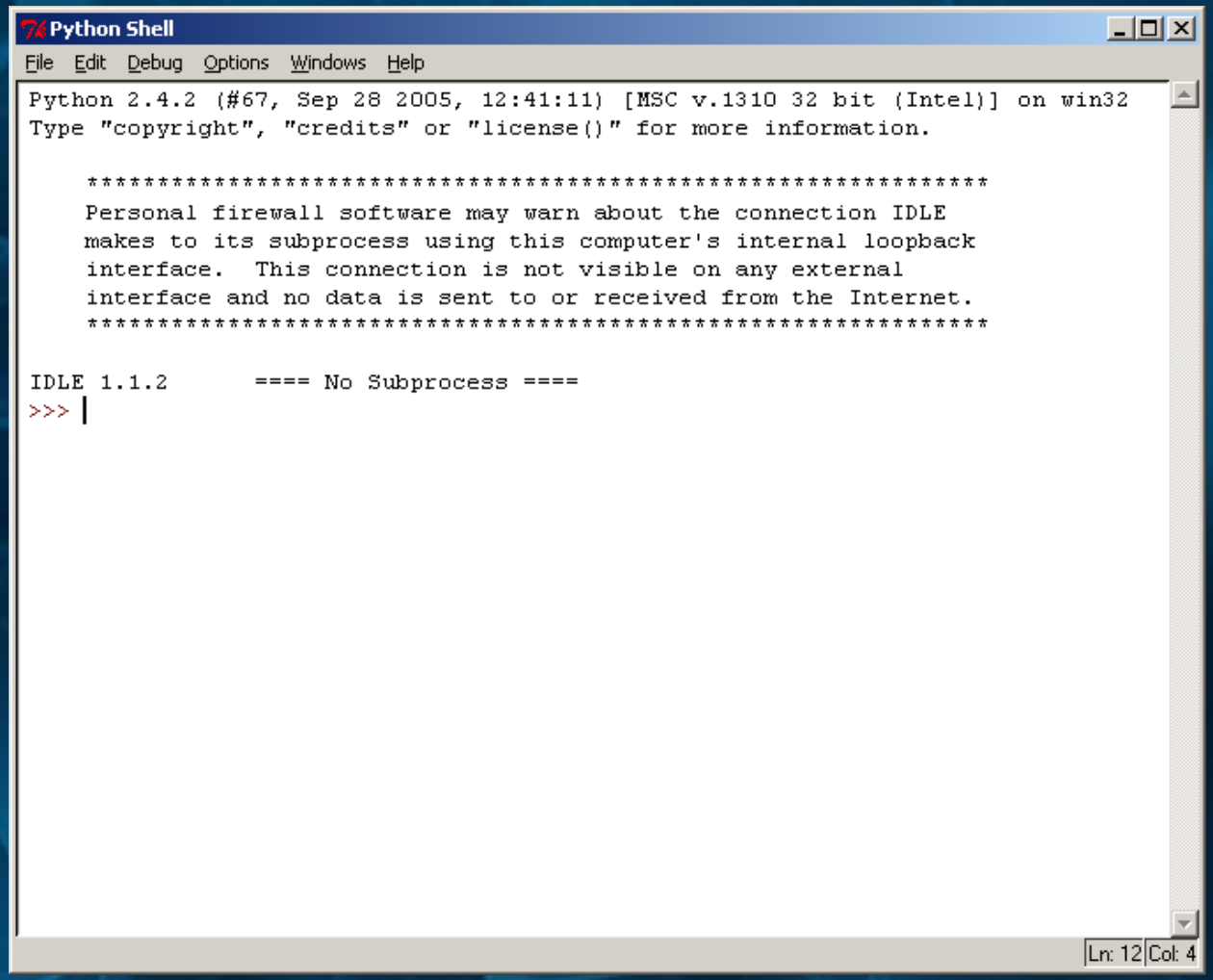
Microsoft Research

Fluke +
Scribbler

USB
Bluetooth
Adapter

Start Python (IDLE)

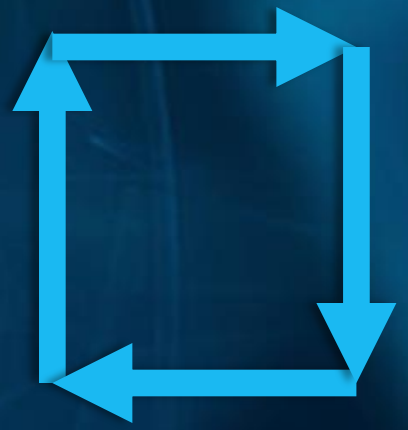
Microsoft Research



Python Library, Myro

Microsoft Research

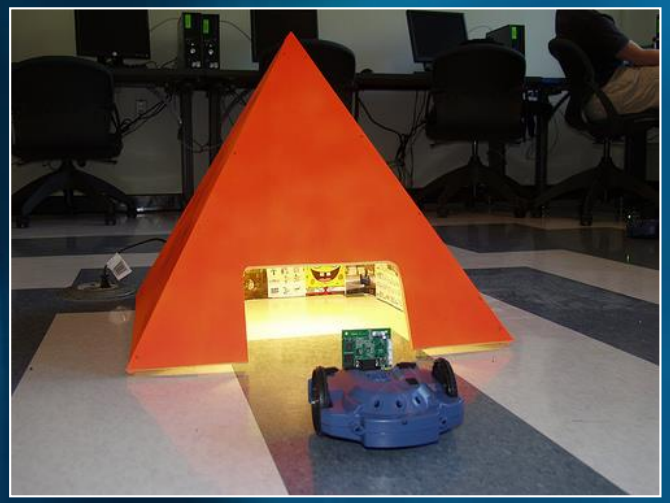
```
from myro import *
init("com5")
setName("Fluffy")
for i in range(4):
  forward(.75, 3)
  turnLeft(1, .3)
  beep(.1, 440)
  speak("Turning...")
speak(getName() + " is done!")
```



Python Library, Myro: Follow the Orange

Microsoft Research

```
from myro import *
init("com5")
while timeRemaining(60):
   pic = takePicture()
   sum, count = 0, 0
   for pixel in getPixels(pic):
            if getColor(pixel) == orange:
                  sum += getX(pixel)
                  count += 1
   if sum/count > getWidth(pic)/2:
            turnRight(1, .2)
   else:
            turnLeft(1, .2)
```



Available from Amazon, FedEx Office, Lulu.com

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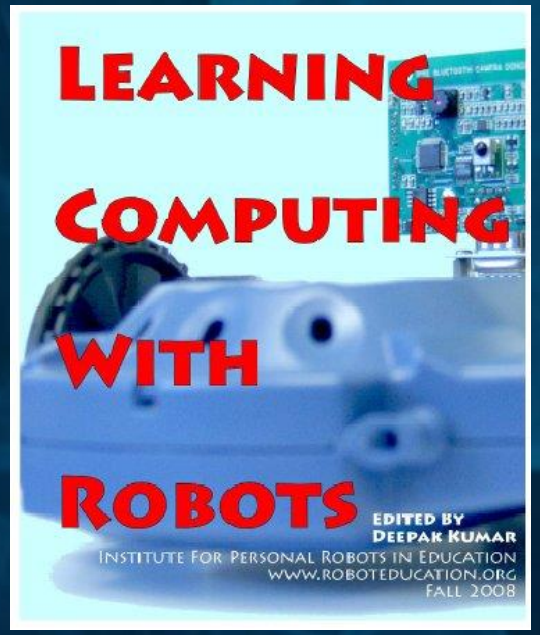


$17.95

$199.90
($99.95 + $99.95)

Second-hand market
also available

Myro Software
Free, and open source
Runs on Windows, Mac, Linux

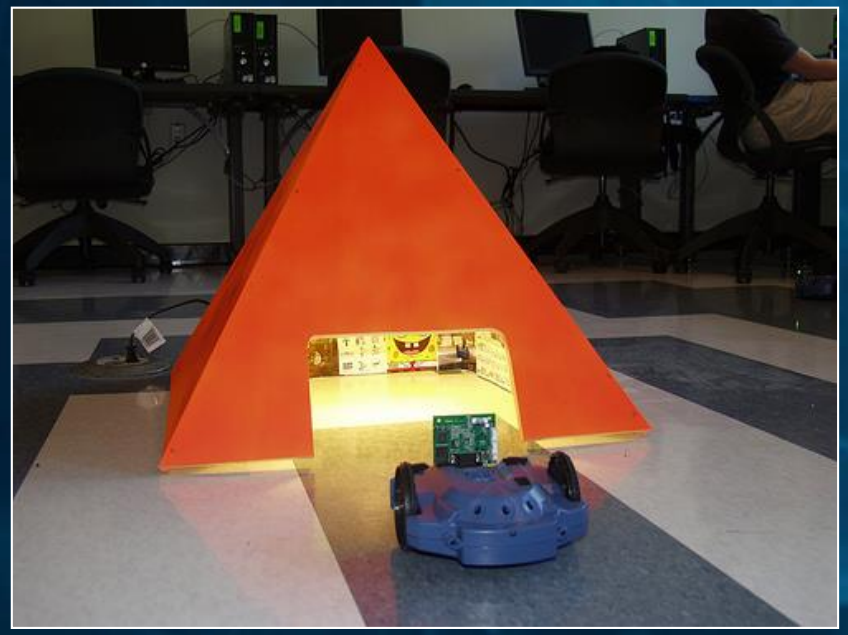
Curriculum Goals

Microsoft Research

- Bring in examples from other related disciplines (e.g., biology, AI, storytelling)
- Explicitly focus on ***robotics*** rather than programming constructs (e.g., chapter titles such as “Building Brains” rather than “Variables” or “Loops”)
- But, implicitly focus on Computing

A CS1 Assignment: Exploring the Pyramid

Microsoft Research



Programming as a Social Activity

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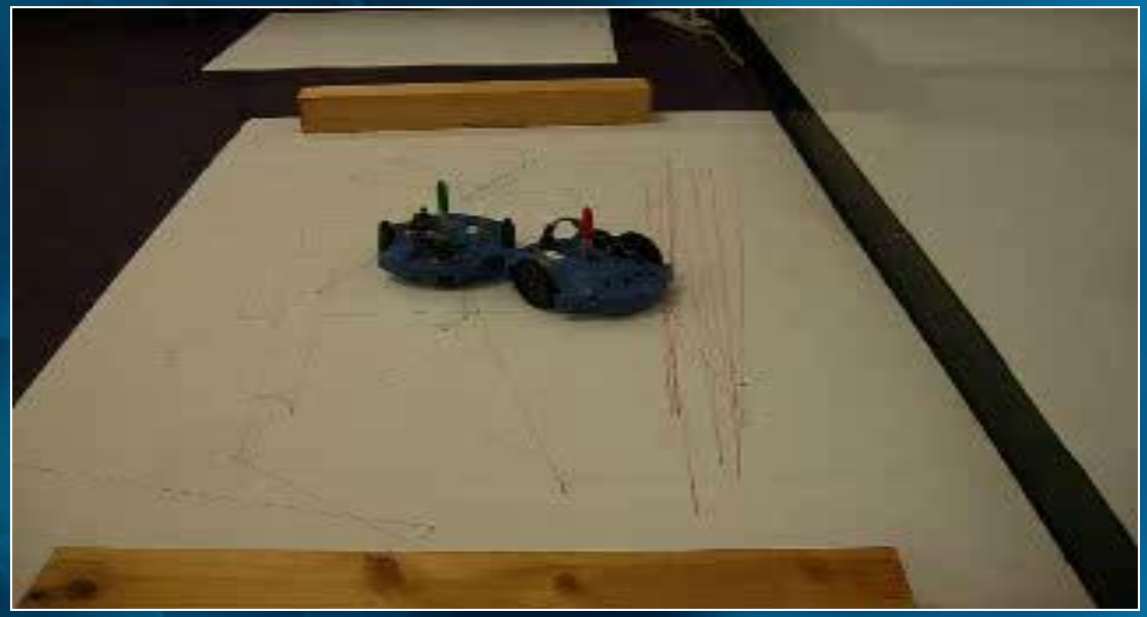

End of Term Robot Group Performance

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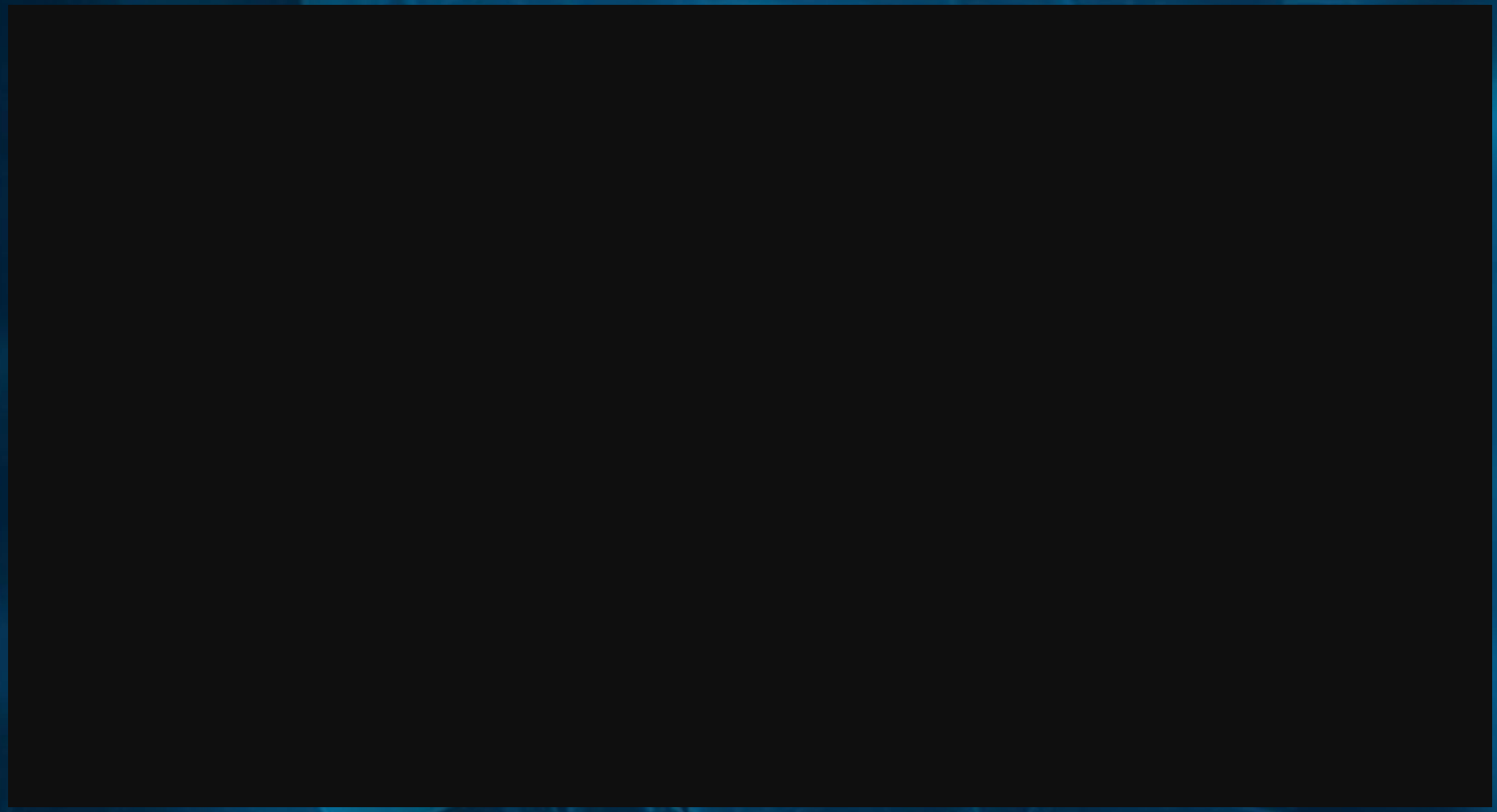

Modeling Animals and Behavior with Robots

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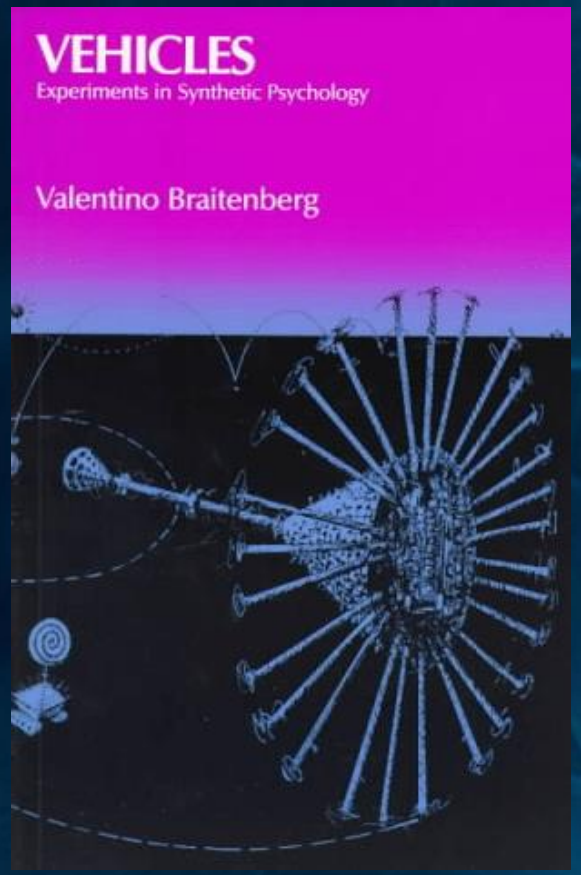

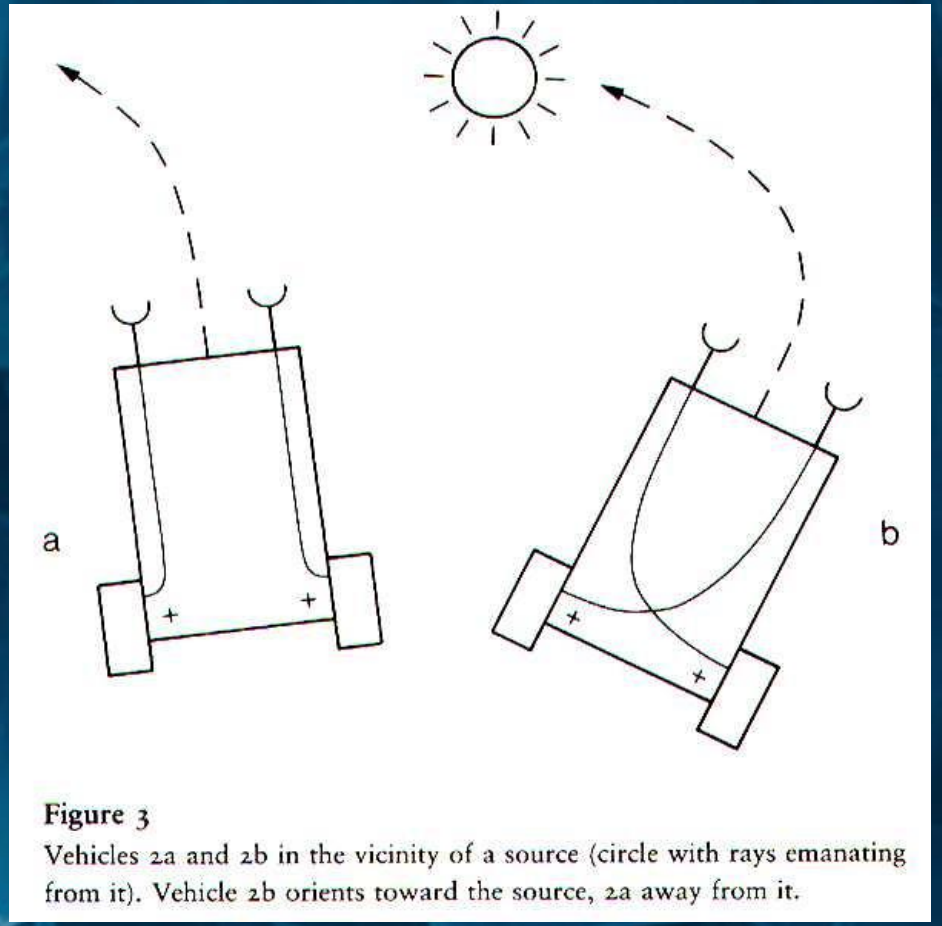

Figure 3
Vehicles 2a and 2b in the vicinity of a source (circle with rays emanating from it). Vehicle 2b orients toward the source, 2a away from it.

Civic Computing

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BRYN MAWR

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- Recent Issues
- Bryn Mawr in the News
- College Publications
- Public Affairs Office

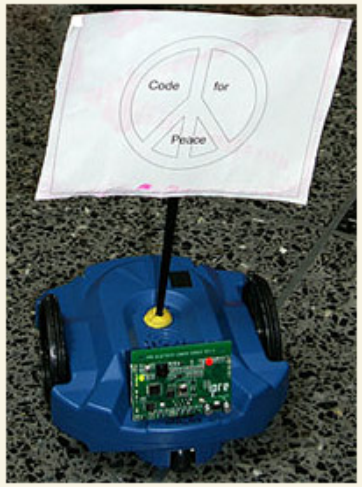
EVENTS
- Campus Events Calendar
- Performing Arts Series
- Visiting Writers Series
- Library Exhibits & Lectures
- Alumnae/i Events Calendar
- Conferences and Events

Search News Archive

Bryn Mawr Now

October 25, 2007

Peacebots Picket Robotic Violence



What do robots do in the real world? They vacuum floors, work on assembly lines, assist with laparoscopic surgery and, as of last Saturday, march for peace.

The peacebots that demonstrated at the Franklin Institute on Oct. 20 were programmed by four students from Associate Professor of Computer Science Doug Blank's introductory course in computer science, which uses

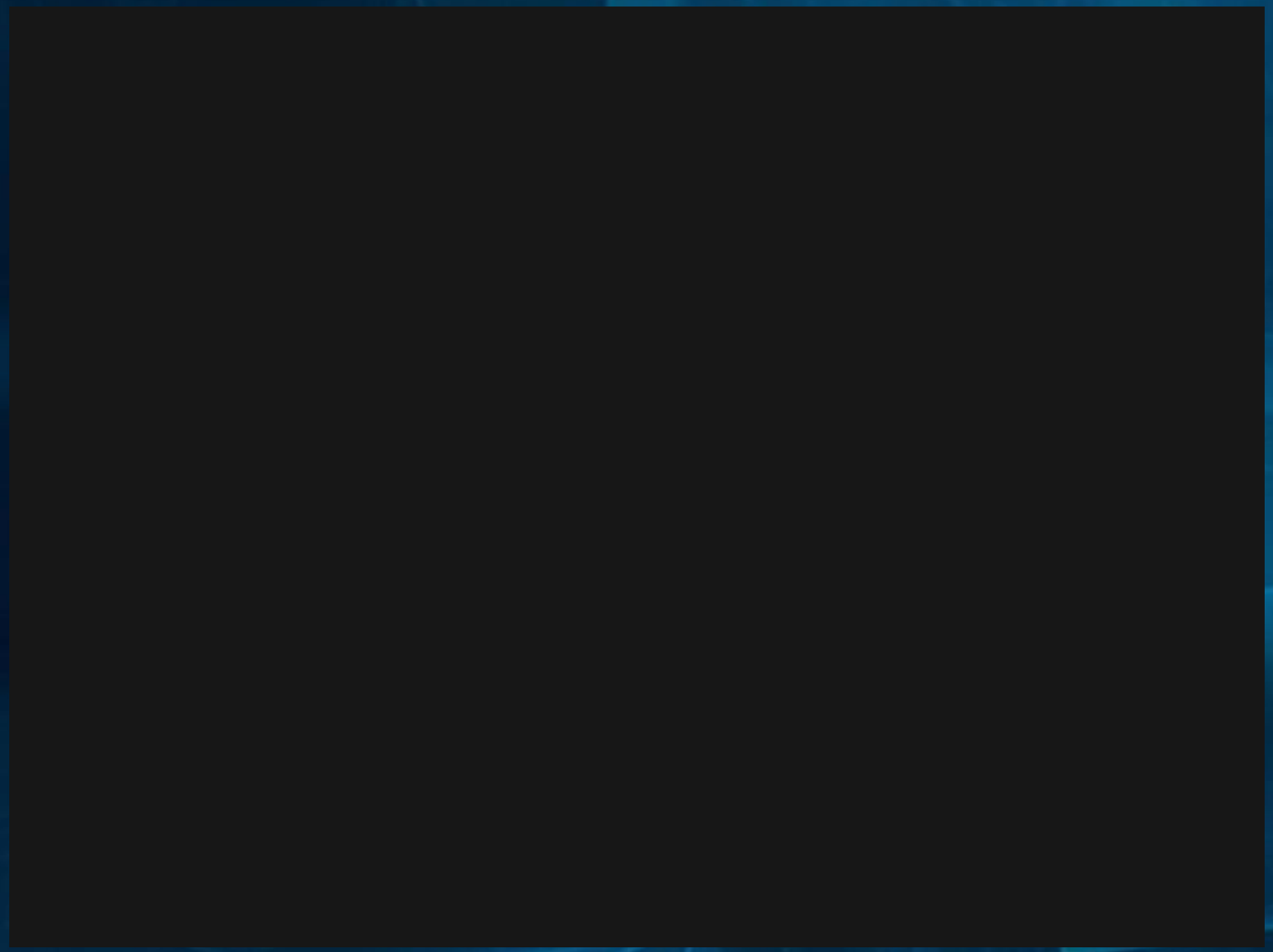
Robot Movies

Microsoft Research

- Wonderful project by Jay Summet and Keith O'Hara:
  Creative, Collaborative – and Distributed/Parallel!
- Robots are characters
  - Multiple characters mean multiple students with multiple robots
  - Challenges:
    How do you know when your actors are in their places?
    How do you "cue" the others?
- One robot is camera
  - How do you zoom?
    Aim and go forward!
- Post-processing media computation for
  eerie disappearing effects

Example Movie with Effects

Microsoft Research



Robots and Instant Messaging & Web

Microsoft Research

Instant Messaging Interface

You can send and receive messages from other Myro users.

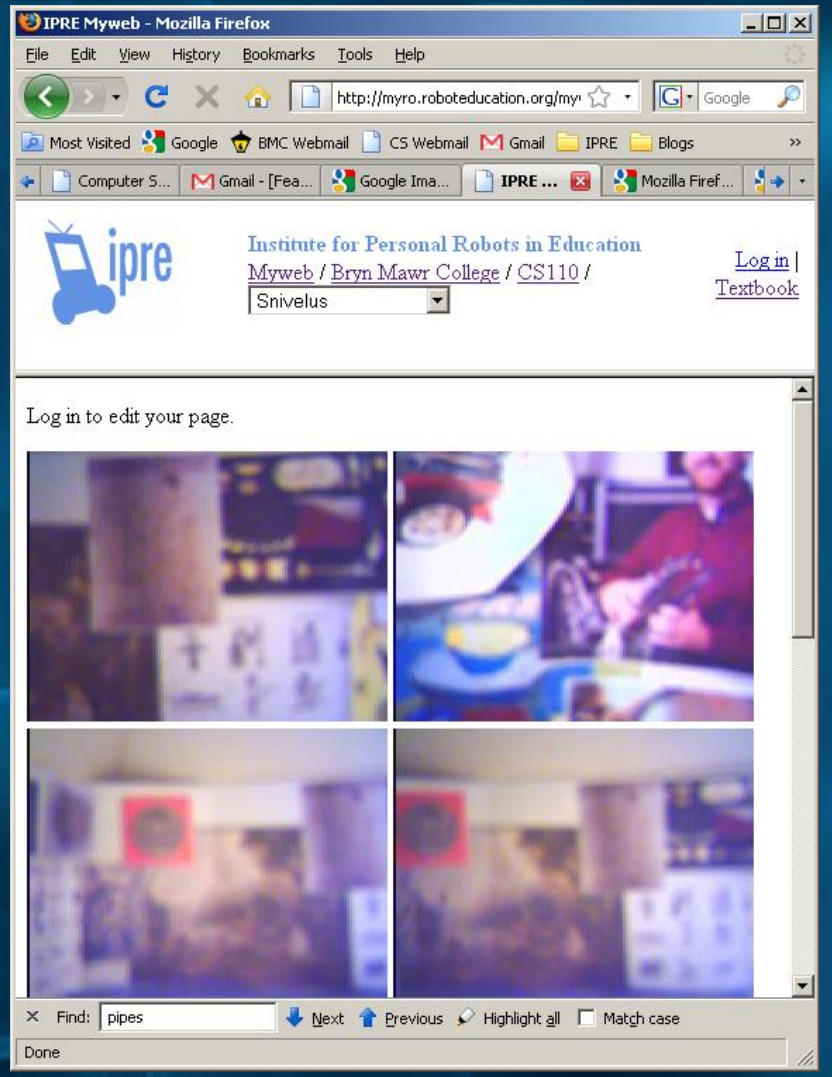
```
>>> chat = Chat("myname", "mypassword")
>>> chat.send("somebodyelse", "Hi, how are you?")
>>> chat.receive()
[("sombodyelse@myro.roboteducation.org", "I'm fine, thanks!")]
```

Remote Robot Control

The robot that will be controlled:

```
>>> robot.initializeRemoteControl("mypassword")
>>> robot.processRemoteControl()
>>> []
>>> robot.processRemoteControlLoop() # threaded, infinite loop
>>>
```

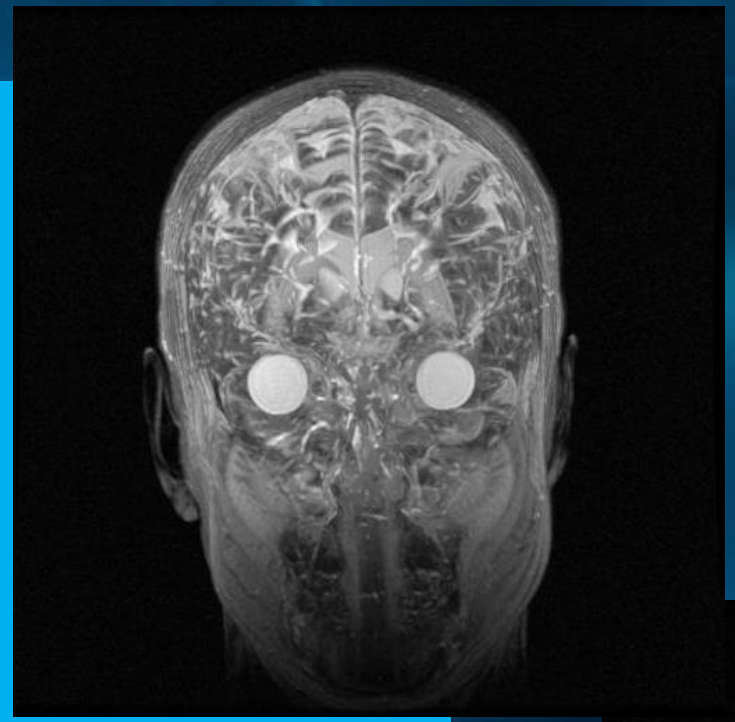
The computer that will be the controller:



Vision and Image Processing

Microsoft Research

```
# Process a set of MRI images
# Doug Blank
from myro import *
filenames = getFilenames("z??.jpg")
filenames.sort() # get in order, back to front
image = None
for filename in filenames:
    print "Processing", filename
    if image == None:
        image = loadPicture(filename)
    else:
        newimage = loadPicture(filename)
        for pixel in getPixels(newimage):
            if distance(getRGB(pixel), getRGB(black)) > 50: # not black
                setPixel(image, getX(pixel), getY(pixel), pixel)
savePicture(image, "composite.jpg")
```



Assessment Results

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- Formative Interviews
- Assessment in 2007
- Robots vs. Non-Robots, 2008/2009
- Distributed Assessment

Formative Interviews

Microsoft Research

- The robot did add a new dimension of excitement to the class.
  - “It made it interesting to apply the computer programming to the robot – was not bland and gave it another dimension.”
  - “Not many people can say 'yes I programmed a robot.' But now I can!”
- The robot was an additional complexity for the students.
  - “Midway through we had tons of Bluetooth issues – I had to blindly write my code and then use someone else’s robot. Was unable to use mine for the last half of the semester and that was no fun.”
  - “My robot died at that point but I would have done lots more than I was asked to do dancing, lights, music, etc.”

Formative Interviews

Microsoft Research

- It took effort to integrate the robot into the course
  - “[I] forgot [in lectures] that we were doing robots.”
  - “We had one designated robotics TA for the whole class but he was only available to us twice a week. If homework is due and it's not time to talk to the TA, then we asked Monica and it was a lot for her. Sometimes the robotics TA didn’t know because it was new to him too.”
  - “[It was] all robot in homework, but not in lecture.”
- Students were anxious about using the robot at first
  - “Thought it would be harder.”
  - “[I was] scared of the robot.”

Assessment Trials

Microsoft Research

- Three main comparative trials so-far:
  - Spring 2007: Attitudes robot (GT and Bryn Mawr) and non-robot (GT)
    - Interviews to establish themes
    - Surveys to test themes across whole class
  - Fall 2007: More careful testing of learning, same groupings
  - Spring 2008 vs. Spring 2009: Comparing similar cohorts, non-robots vs. robots

Attitude Results

Microsoft Research

- All students enjoyed the robot, were comfortable with it, and found it easy to get working
  - Personalizing the robot improved the course, in students' opinion
- Reported that the class was about ***computer science***
- Found homework challenging

GT/BMC Attitude Differences

Microsoft Research

- BMC students did more on homework "because it was cool."
- BMC students were undeclared majors
  - Reported being more excited about CS afterward
- GT students were already declared majors
  - Less excited about robots overall, but more interested than BMC in more courses in computer science
  - Tended not to talk about the course to others

Fall 2007 Final Exam Comparison

Microsoft Research

- The final exam taken by all students had five shared questions
- Shared questions did not require experience with the robot, but in some cases used “robotic” situations

Robot Recursion (11 points)

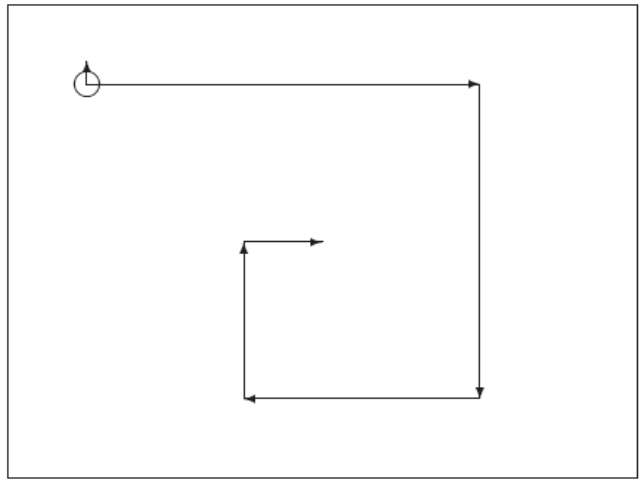
The following code makes the robot drive the trajectory drawn in the box to the right.

```
def turnR90():
    turnRight(1, 1)

def nudge(x):
    forward(1, x)

def go(x):
    while x > 0:
       turnR90()
       nudge(x)
       x = x - 1

go(5)
```



Rewrite `go()` using recursion instead of a while loop.

Results: Robot Students did 10% Better

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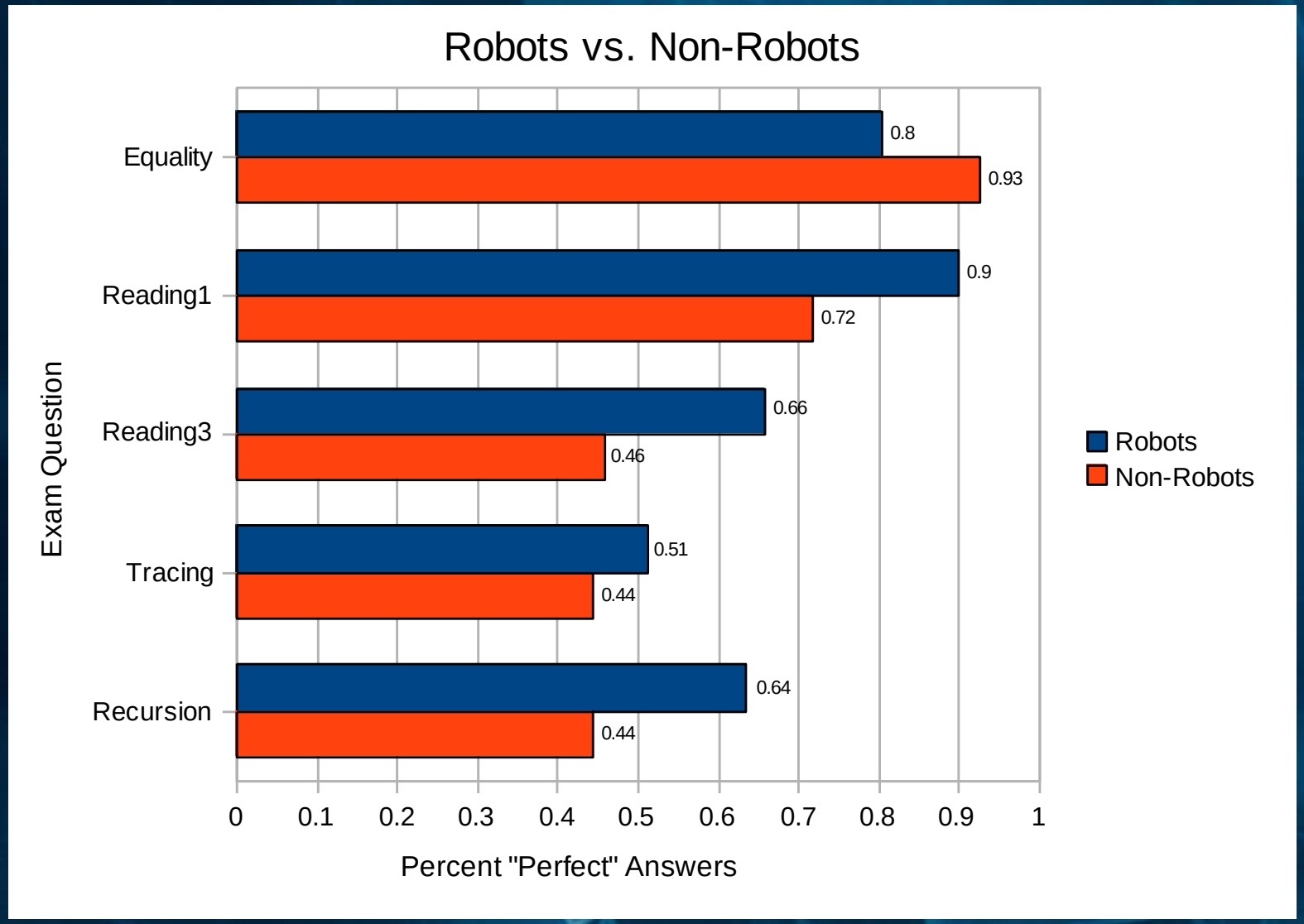

All but Tracing question were significant at $p < 0.05$

Demographics *Matter*

Microsoft Research

- Due to the laptop requirement, advisors steered students who were declared as CS majors into the robots class, and other students into the non-robots class
- 4% CS/Computation Majors in the Non-Robots class
- 81% CS/Computation majors in Instructor B's Robots class

Grades Don't Matter, Leaving Does

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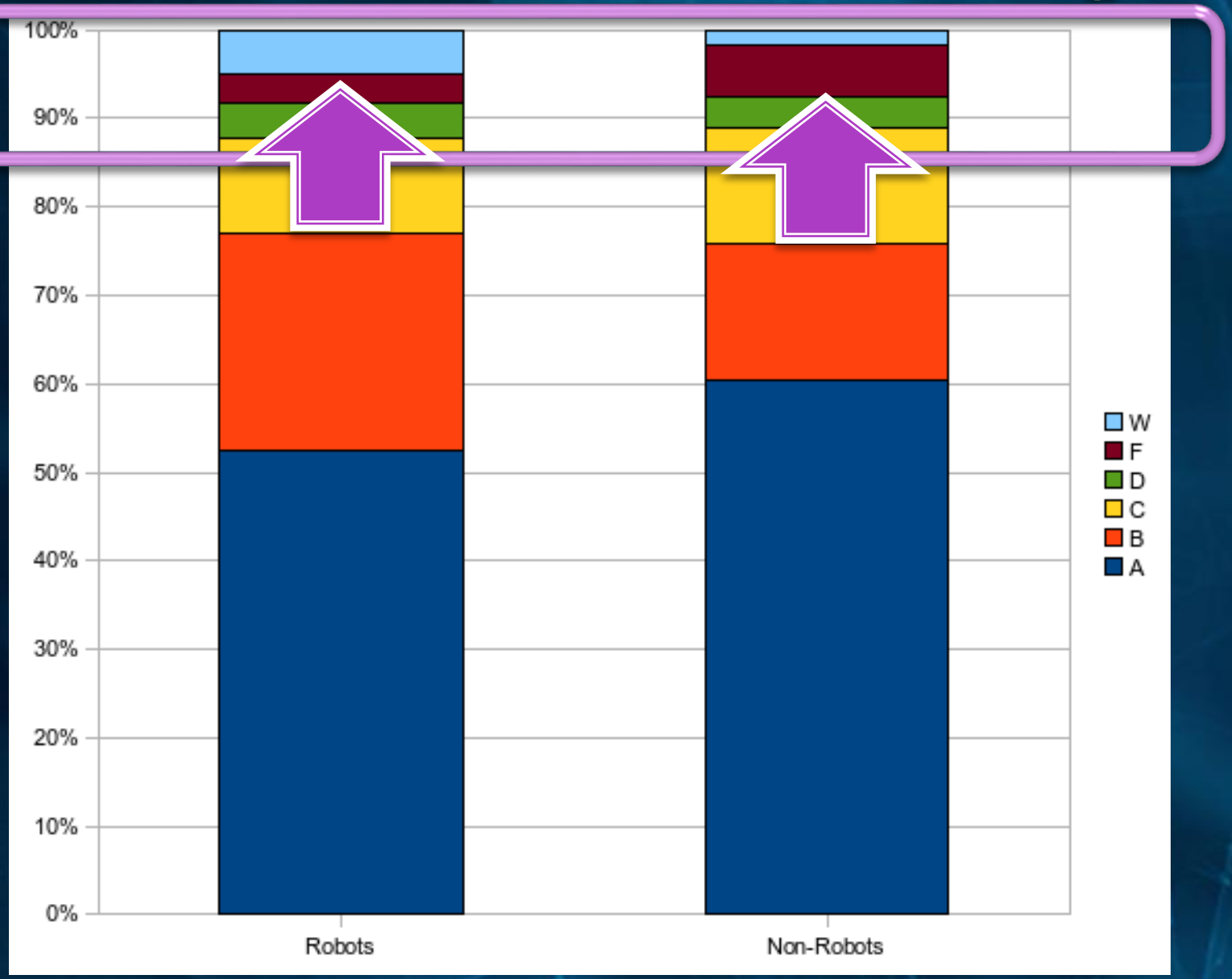

Spring 2008 Non-Robots vs. Spring 2009 Robots

Microsoft Research

- Comparing robots vs. non-robots with demographics controlled:
  - No difference in grade distribution
  - No difference in pass/fail (WDF) rates
- Only 33% of enrolled students *had prior knowledge* that it was a robots class. Of those:
  - 35% of students said that the robot was a positive influence on taking the course
  - 15% said it was a negative influence: Cost, then complexity

Attitude Differences (Significant)

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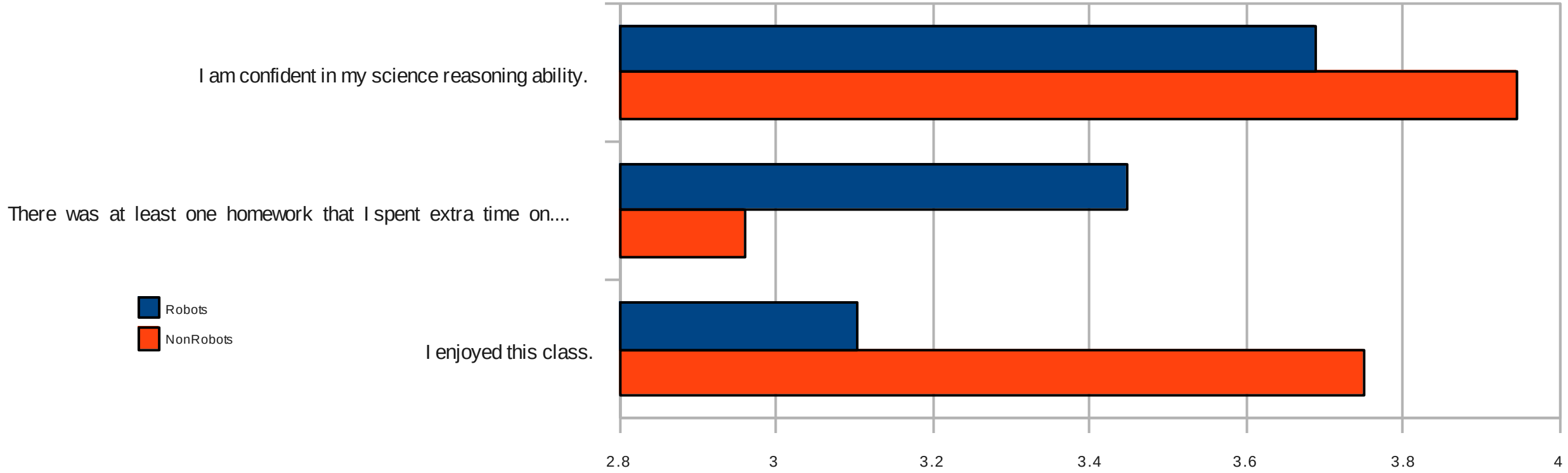

Cultural Impact of Robotics at BMC

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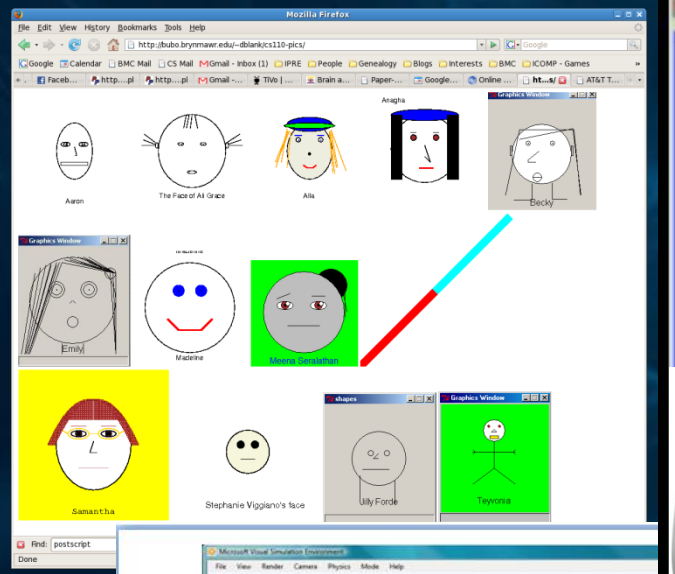

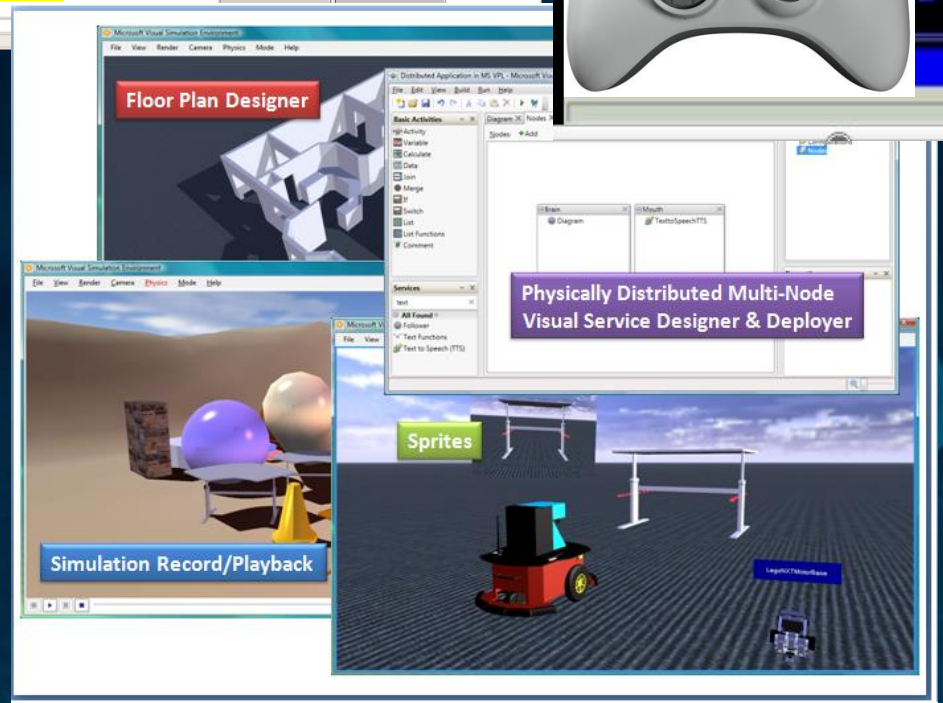

r similar wind instrument (*Saxofony*

- **(*stiffness*)**: set reed stiffness (0.0 <
- **(*aperture*)**: set reed aperture (0.0 <
- **(*pressure*)**: set pressure / volume
- ***vibratoFreq*, *vibratoGain*, *noiseG***

- **sition(*position*)**: set blow position
- **g(*strength*)**: start blowing (0.0 <=
- **g(*strength*)**: stop blowing (0.0 <=
- **setAttackRate(*seconds*)**: set rate of attack (so

MoogSynthesizer

A Moog synthesizer (*Moog* in ChucK)

- **setFilterQ(*floatValue*)**: set filter's Q value (0.0
- **setFilterSweepRate(*rate*)**: set filter sweep rat
- **setVibrato(*freq*, *gain*)**: set frequency and gain
- **setAfterTouch(*afterTouch*)**: set aftertouch (0.0

StruckBar

Struck bar instruments (*ModalBar* in ChucK)

Orchestrating

After you get familiar with a single instrument, then you migl
instrument.

```
from myro import *
from myro.chuck import *

initChuck()

def playSaxophone():
    sax = Saxophone()
    sax.connect()
    sax.startBlowing(1)
    wait(1)
    sax.stopBlowing(1)

def playMandolin():
    mandolin = Mandolin()
    mandolin.connect()
    mandolin.pluck(1)
    wait(1)
```

You can test each one of those independently by simply rur

```
playSaxophone()
```

Once you have more than one intrument function written, yo

```
doTogether(playSaxophone, playMandolin)
```

BMC Seeing Dramatic Enrollment and Retention Increases

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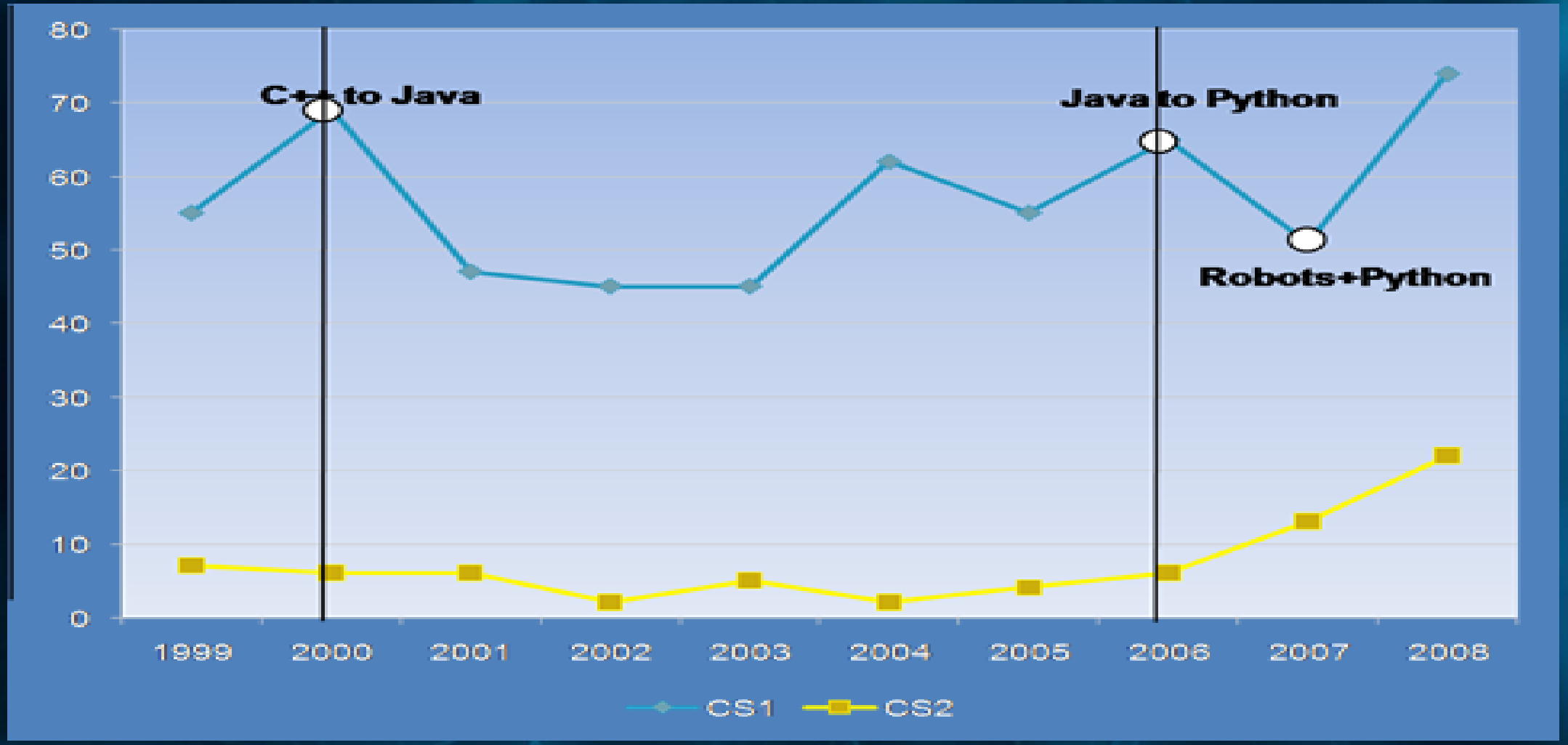


Distributed Assessment

Microsoft Research

- Several schools (out of 25 associates) seeded with robots and funds to work with us on assessment
  - Shorter College
  - Rowan University
  - Georgia State University
  - The University of Tennessee – Knoxville
  - The University at Albany – SUNY
  - Phillips Exeter Academy

Consider GSU and UTK Attitude Differences

Microsoft Research

- Statements with statistically significant differences
- Non-Robots Students more often agreed:
  - “I enjoyed this class.”
  - “I enjoy being challenged by seemingly unsolvable situations or problems.”
- Robots Students more often agreed:
  - “I discuss difficult assignments and/or detailed lectures with friends in the class.”

Bottom Line: Assessment

Microsoft Research

- Students' attitudes:
  - See value of robots, though some are more anxious because of robots
  - Focus: Robotics as *context* for *computer science*
  - For some students, robot use encouraged social activity and led to more engagement with computing
  - *Personal* nature of robots *is* important
- No observed impact on CS1 success
  - Robots made computing more tangible, might be impacting student success more subtly
- May be having a dramatic impact on CS2
- Future: Individual and cultural impacts

Community Efforts

Microsoft Research

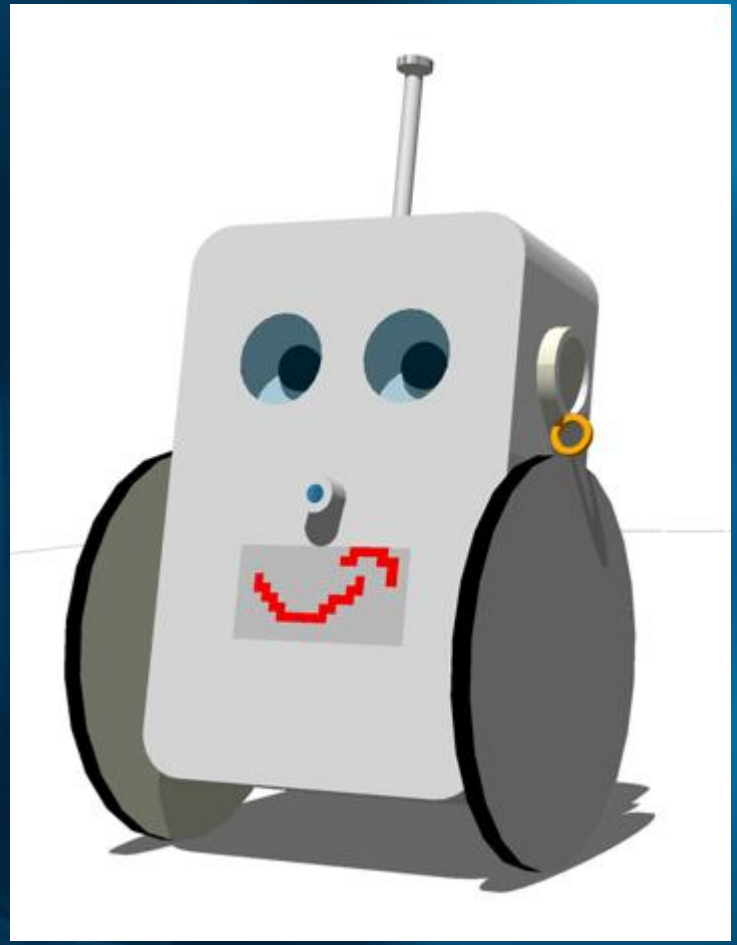
- Online textbook and teaching resources (wiki)
- Online source code (SVN accessible)
- Online mailing lists
- 25 small grants for colleges to try IPRE materials, develop new materials, work with us on assessment
- Summer faculty workshops
- Workshop and conferences organization
  - RSS, ICRA, SIGCSE, MSR Faculty Summits
- Robot Education Bibliography
  - `http://biblio.roboteducation.org`

`http://wiki.roboteducation.org`

IPRE Phase 2

Microsoft Research

- Seeking NSF Funding for next two years
- Develop an infrastructure for many languages and additional libraries
- Completing the Gyro Hardware
- Use the Dynamic Language Runtime (DLR)
- Further develop the robo-ed community
- Dissemination to the broader CS Ed community



Myro V3.0 and Pyjama

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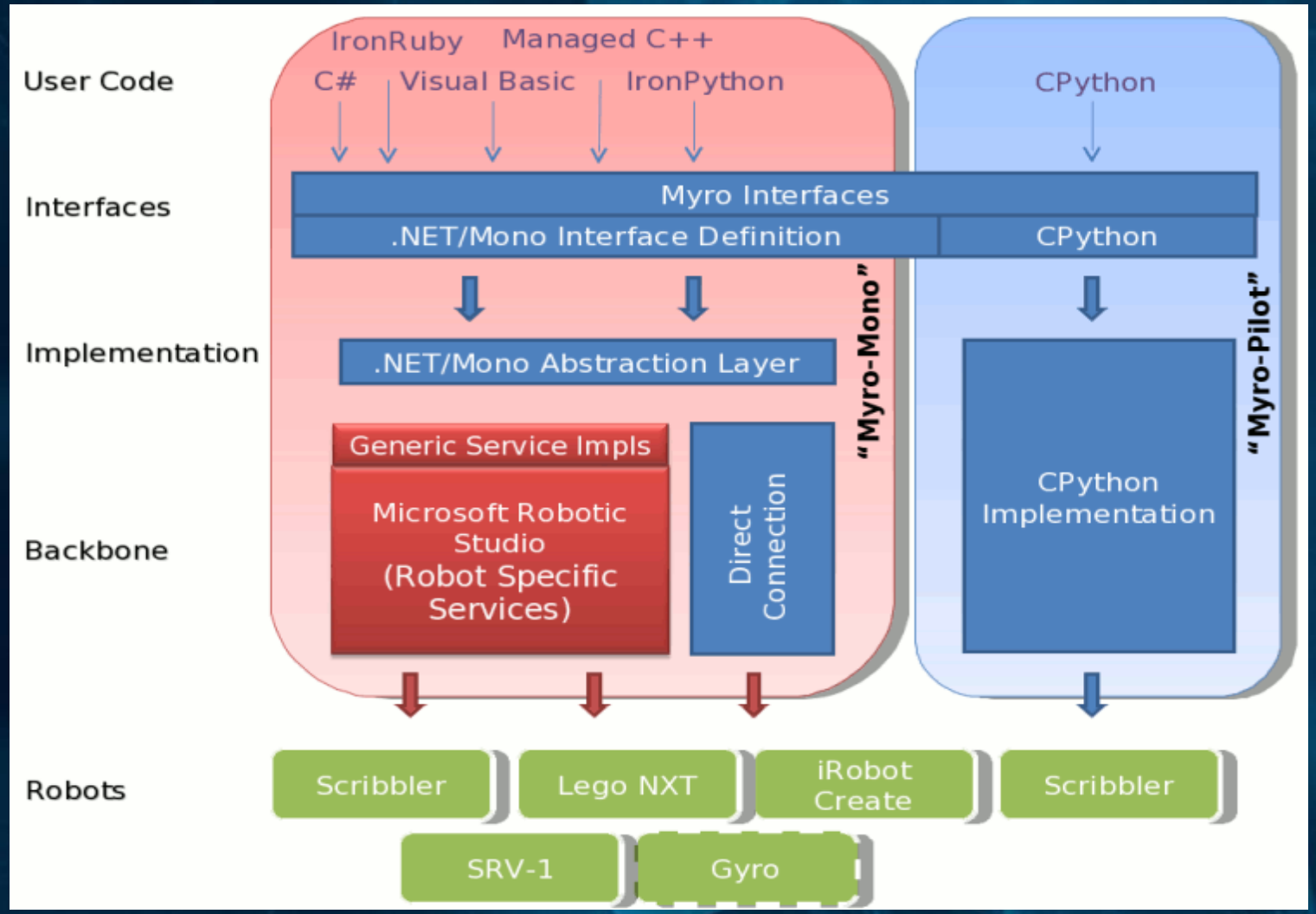
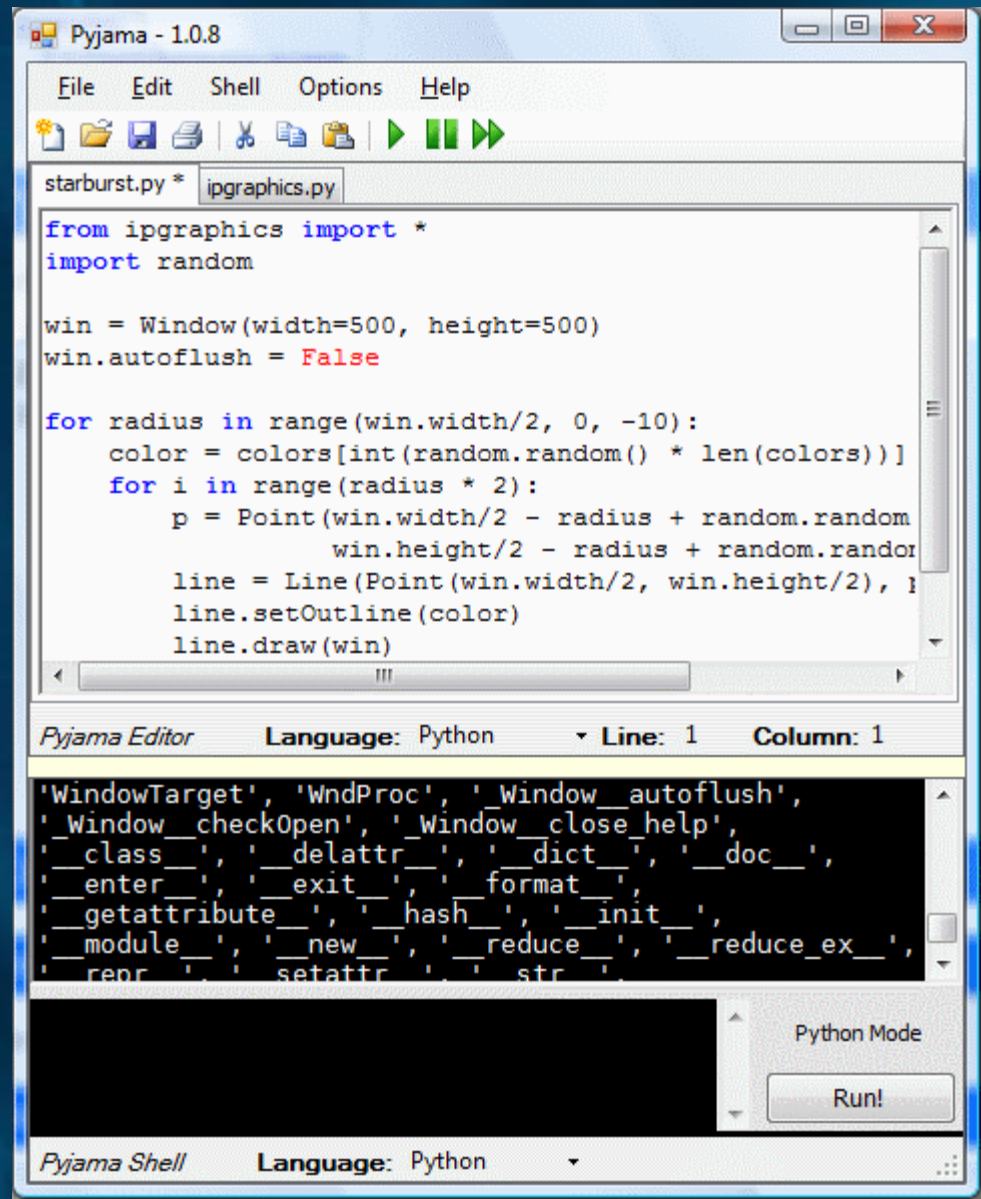
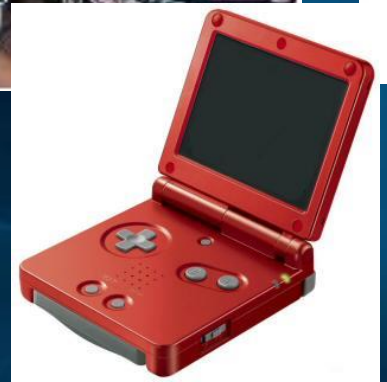




What Else Do We Know About Context in Computing Ed?

Microsoft Research

- Media Computation CS1:
  - Impacts at multiple institutions on CS1 retention, both majors and non-majors
- Media Computation Data Structures:
  - Improved retention, more time-on-task
- Girl Scouts Workshops:
  - Big winners: Scratch, Alice, PICO Crickets, Pleos
    - Not-so-much: Lego Robotics
- Computer Organization with Gameboys
  - No learning difference, big motivation difference and time-on-task



What Don't We Know

Microsoft Research

- What's a context?
  - Why aren't prime numbers and Fibonacci numbers a context for students today?
- What makes a context *relevant*?
- What's the learning impact of context?
  The social impact? The long term impact?
- What leads to real literacy?

Beyond More Majors: Achieving Computing Literacy For All

Microsoft Research

- If students don't buy into Computing to start, "Computing Literacy" is just another subject
  - Programming is detail-oriented, unforgiving. It's hard.
- Teaching with a context explains to students what the Computing is *for*
  - May enhance learning of the context, too
- To use Computing as a lens on the world, requires really learning Computing
  - What motivates that investment?

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  - Georgia Tech & Bryn Mawr College
- And of course the community…

IPRE Associate Institutions

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- Arkansas Tech University
- Austin College, TX
- Brooklyn College
- Canisius College
- Fayetteville State University
- Florida Virtual School
- Georgia State University
- Haddonfield Memorial High School
- Hammond School
- Harvey Mudd College
- Indiana University
- Ithaca College
- Olin University
- Park University
- Phillips Exeter Academy
- Presbyterian College
- Rochester Institute of Technology
- Rollins College
- Rowan University
- St. Xavier University
- Stetson University
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