Robots as a Context for Teaching Beginner Programmers: The Conclusion of Three Years' Research at IPRE

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For Co-PI’s
Tucker Balch (GT),
Doug Blank & Deepak Kumar (BMC)
With
Stewart Tansley (MSR)
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?
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
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?
What We’re Doing Is Not Working

How do we engage these students?

- **Women Among CS Bachelor’s Degrees**
  - Source: NSF
  - Total degrees granted, left scale
  - Share of total, right scale
  - Degrees granted to women, left scale

- **CS and CE listed as probable majors among incoming freshmen**
  - Source: HERI at UCLA
  - Computer Science
  - Computer Engineering

Note: no data were reported for 1999
Why Should They Care?

Algorithms

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

Consumers and companies increasingly depend on a high

the two cultures and the scientific revolution

C. P. SNOW
How Do We Teach Computing to Those Who Care About Context?

1. A subject that may intersect a context

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*

Lewis & Smith, ACM SIGCSE *inroads*, June 2005
Mark: That's when the forces are equal then, right?
Mark: $R = mg$.
Roger: At T, some T.
An Education Research Project

Mission: Make CS education more fun and 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

- Curriculum
- Community
- Assessment
- Software
- Hardware
History-at-a-Glance of the Project

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 22\textsuperscript{nd} 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
# 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?

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

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

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

USB Bluetooth Adapter

Myro

Fluke + Scribbler
Start Python (IDLE)

Python 2.4.2 (#67, Sep 26 2005, 12:41:11) [MSC v.1310 32 bit (Intel)] on win32
Type "copyright", "credits" or "license()" for more information.

******************************************************************************
Personal firewall software may warn about the connection IDLE makes to its subprocess using this computer's internal loopback interface. This connection is not visible on any external interface and no data is sent to or received from the Internet.
******************************************************************************

IDLE 1.1.2

>>> |

Start Python.pyw
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!")
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

$17.95

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

$199.90
($99.95 + $99.95)

Second-hand market also available
Curriculum Goals

- 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
ACS1 Assignment: Exploring the Pyramid
Programming as a Social Activity
End of Term Robot Group Performance
Figure 3
Vehicles 2a and 2b in the vicinity of a source (circle with rays emanating from it). Vehicle 2b orient toward the source, 2a away from it.
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
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
Robots and Instant Messaging & Web

**Instant Messaging Interface**

You can send and receive messages from other Myro users.

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

**Remote Robot Control**

The robot that will be controlled:

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

- Formative Interviews
- Assessment in 2007
- Distributed Assessment
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.”
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.”
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
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.
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
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.

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**Robot Recursion (11 points)**

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

```python
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

All but Tracing question were significant at $p < 0.05$
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
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
I enjoyed this class.

There was at least one homework that I spent extra time on....

I am confident in my science reasoning ability.

2.8 3 3.2 3.4 3.6 3.8 4

Robots
NonRobots

I enjoyed this class.
Cultural Impact of Robotics at BMC

Orchestrating

After you get familiar with a single instrument, then you might use more:

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

initChuck()

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

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

You can test each one of those independently by simply running:

playSaxophone()

Once you have more than one instrument function written, you could:

dotogether (playSaxophone, playMandolin)
```

MoogSynthesizer

A Moog synthesizer (Moog in Chuck):

- setFilterQ(floatValue): set filter’s Q value (0.0 - 1.0)
- setFilterSweepRate(rate): set filter sweep rate
- setVibrato(freq, gain): set frequency and gain
- setAfterTouch(afterTouch): set aftertouch (0.0 - 1.0)

StruckBar

Struck bar instruments (ModeBar in Chuck)
BMC Seeing Dramatic Enrollment and Retention Increases

![Graph showing enrollment and retention trends over time.](image-url)
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

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.”
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

- 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.robotechnology.org

http://wiki.robotechnology.org
IPRE Phase 2

- 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
What Else Do We Know About Context in Computing Ed?

- **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

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?
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?
The team:
- Doug Blank, Tucker Balch, Deepak Kumar, Stewart Tansley, Mark Guzdial, Keith O’Hara, Jay Summet, Jared Jackson, Natasha Eilbert, Daniel Walker, Gaurav Gupta, Monica Sweat, Richard Roberts

The sponsors:
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- Georgia Tech & Bryn Mawr College

And of course the community…
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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