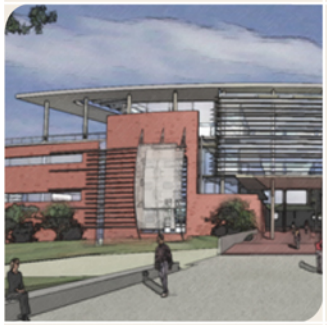
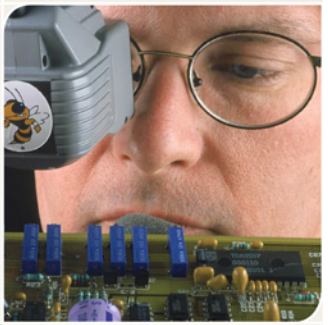


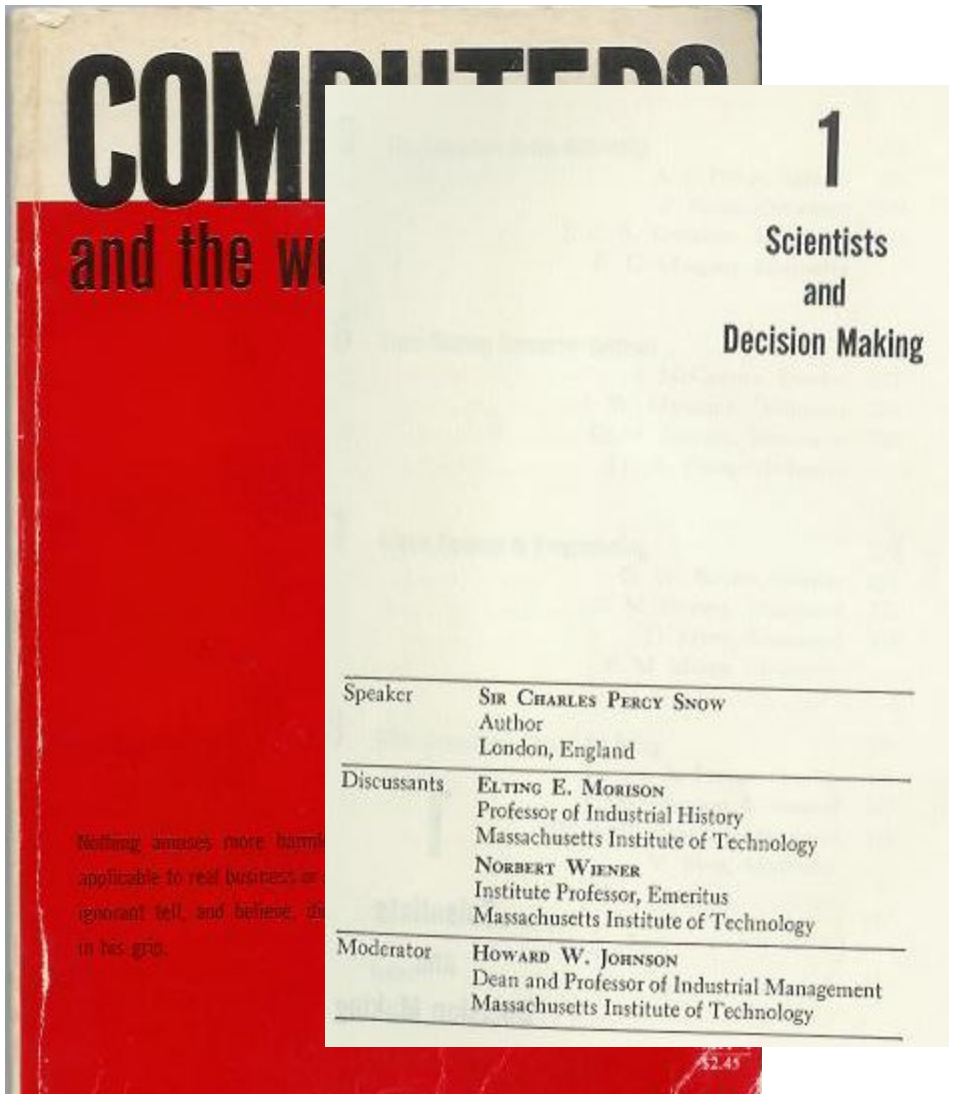


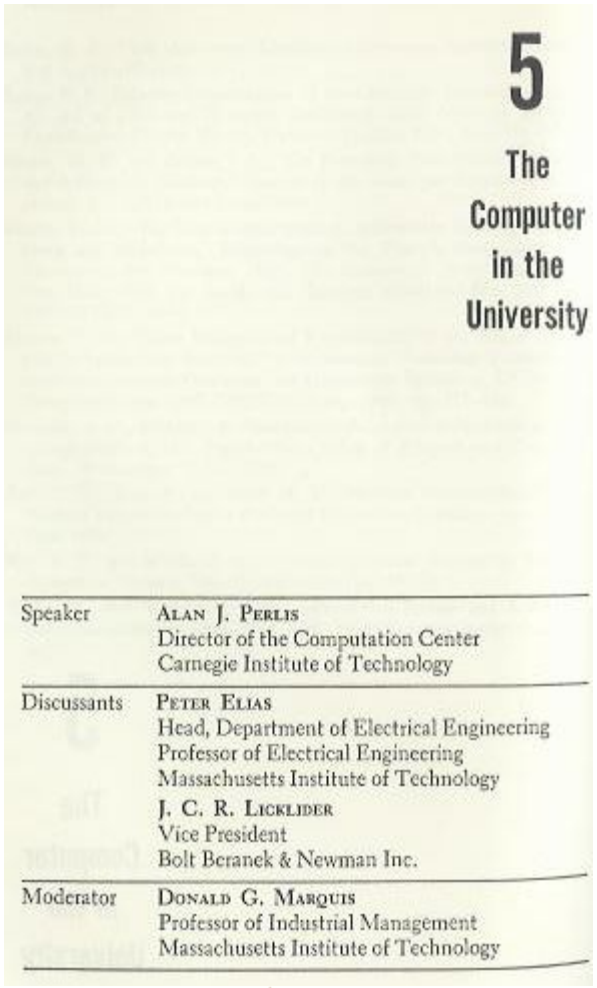

What we know about teaching CS (Answer: Not all that much)

Mark Guzdial
School of Interactive Computing

Georgia Tech College of Computing

1961 MIT Sloan School Symposium





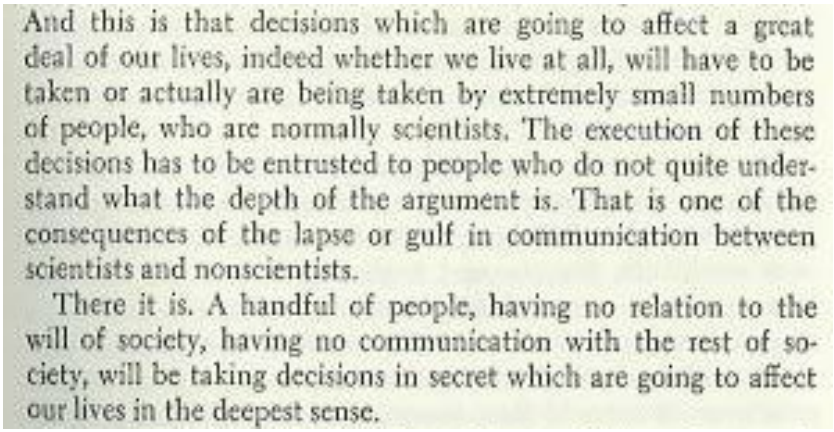
Georgia Tech College of Computing

Learn Programming to Re-Think Process Everywhere

- Alan Perlis argued that computer science should be part of a liberal education.
  - Explicitly, he argued that all students should learn to program.
- Why?
  - Because Computer Science is the study of process.
  - Automated execution of process changes everything
    - Including how we think about things we already know

The Power and Fear of Algorithms

- The Economist (Sept., 2007) spoke to the algorithms that control us, yet we don't understand.
  - Credit Ratings, Adjustable Rate Mortgages, Search Rankings



And this is that decisions which are going to affect a great deal of our lives, indeed whether we live at all, will have to be taken or actually are being taken by extremely small numbers of people, who are normally scientists. The execution of these decisions has to be entrusted to people who do not quite understand what the depth of the argument is. That is one of the consequences of the lapse or gulf in communication between scientists and nonscientists.

There it is. A handful of people, having no relation to the will of society, having no communication with the rest of society, will be taking decisions in secret which are going to affect our lives in the deepest sense.

Economist.com **BUSINESS**

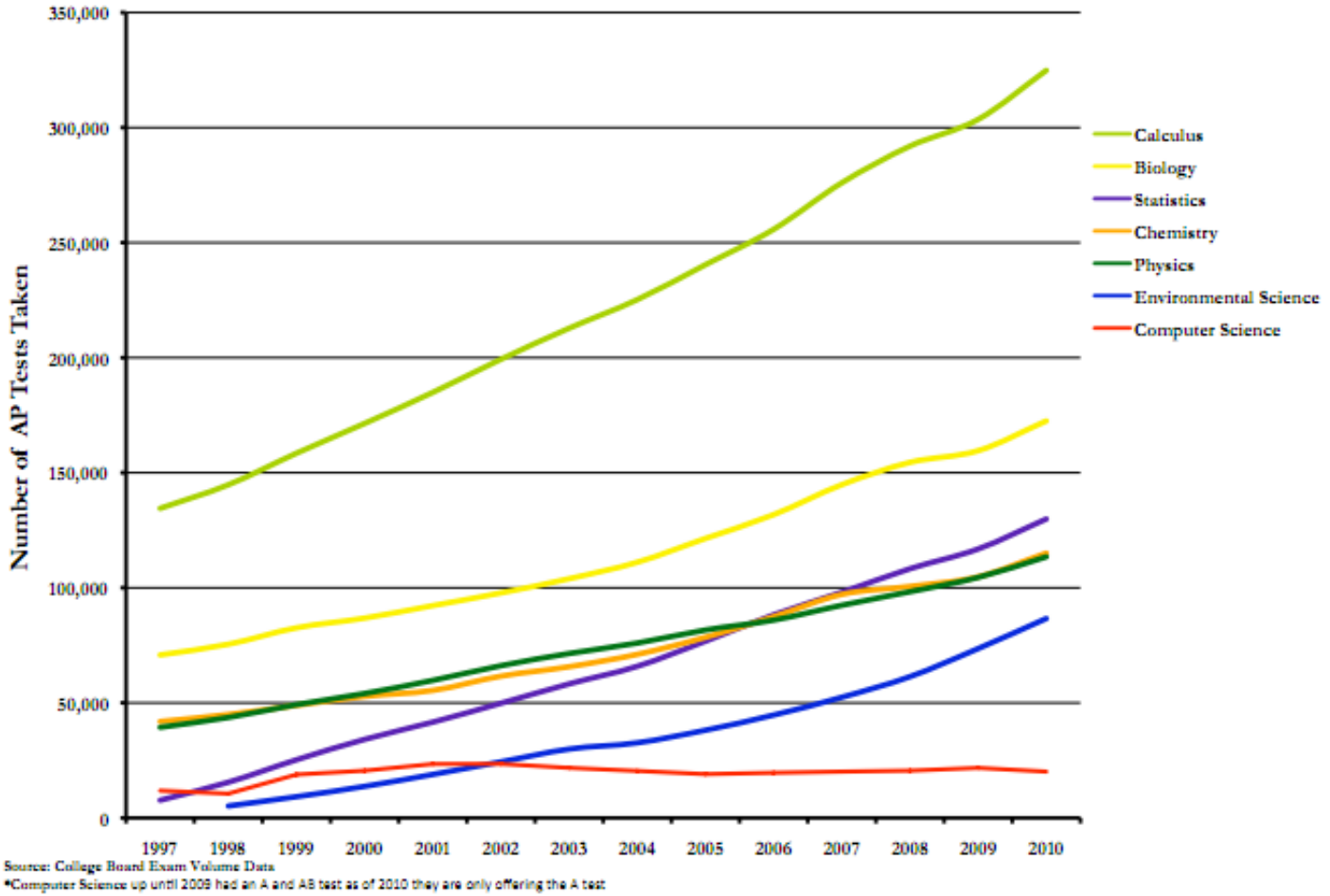
Algorithms

Business by numbers

Sep 13th 2007
From The Economist print edition

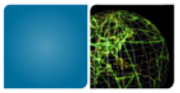
Consumers and companies increasingly depend on a hidden mathematical world

High School Participation in AP STEM Disciplines

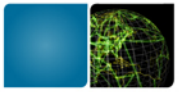


— Chris Stephenson, CSTA, 2010

Need is greater than capacity

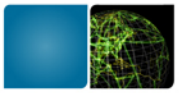




- *Computer Science has a much larger potential audience beyond software developers.*
  - Estimates:
    ~13 million non-professional programmer/end-user programmers in US by 2012,
    vs.
    ~3 million professional software developers (Scaffidi, Shaw, & Myers, 2005)
- Our track record for the first CS course is poor: 30-50% failure or withdrawal rates (Bennedsen & Caspersen, 2007)
  - Worse with female and URM students (Margolis & Fisher, 2003)

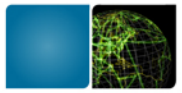

Story

- We want to teach computing to everyone, but *how?*
- Historically: CS is really hard to learn.
- What helps?
  1. Context
  2. Collaboration (Sometimes)
  3. Restructuring learning
  4. Fitting into the learner's life (We hope)

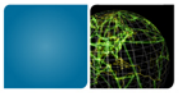

The Rainfall Problem

- Problem: Read in integers that represent daily rainfall, and printout the average daily rainfall.
  - If the input value of rainfall is less than zero is less than zero, prompt the user for a new rainfall.
- When you read in 99999, print out the average of the positive integers that were input other than 99999.

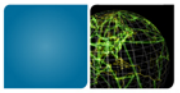

Results at Yale in Pascal in 1983

	% of Students who got it right
Novices (3/4 through first course)	14%
Intermediates (3/4 through second course)	36%
Advanced (Jrs and Srs in Systems Programming)	69%

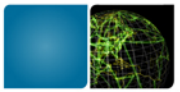

Not an anomaly

- Elliot Soloway and his students replicated this study many times.
- Others have used this same problem with similar results (Most recently: Venable, Tan, and Lister, 2009)
- Anecdotally, every institution I've been at has attempted this problem, with similar results.


MIMN Studies

- "Is it just Yale? Is it just Yale and Pascal?"
- In 2001, Mike McCracken et al. gathered data from 216 students in 5 institutions in 4 countries: "Build a calculator."
  - Out of a possible 110 points, average score was 22.89.


Lister's Response

- "Maybe the problem is design. Can they at least *read* code?"
- In 2004, Raymond Lister gathered even more students, from more institutions and countries.
- Overall score: About 40%

Question 5.
Consider the following code fragment:

```
int[ ] x = {0, 1, 2, 3};
int temp;
int i = 0;
int j = x.length-1;

while (i < j)
{
      temp = x[i];
      x[i] = x[j];
      x[j] = 2*temp;
      i++;
      j--;
}
```

After this code is executed, array "x" contains the values:

a) {3, 2, 2, 0}
b) {0, 1, 2, 3}
c) {3, 2, 1, 0}
d) {0, 2, 4, 6}
e) {6, 4, 2, 0}

Maybe these are just poor tests?

- Allison Elliott Tew built the first language-independent validated test of CS1 knowledge.
  - Domain chosen from review of CS1 textbooks.
  - Expert panel reviewed problems
  - Multiple iteration with think-aloud protocols
  - 950 subjects from two countries.

Table 16: Significant Pearson Correlations between Pseudo-code and CS1 Language Versions of the FCS1 Assessment

Population	df	r	p
Total	850	.572	<= 0.001
Java	74	.665	<= 0.001
Matlab	491	.547	<= 0.001
Python	285	.415	<= 0.001
CS-Python	43	.615	<= 0.001
Media-Python	242	.372	<= 0.001

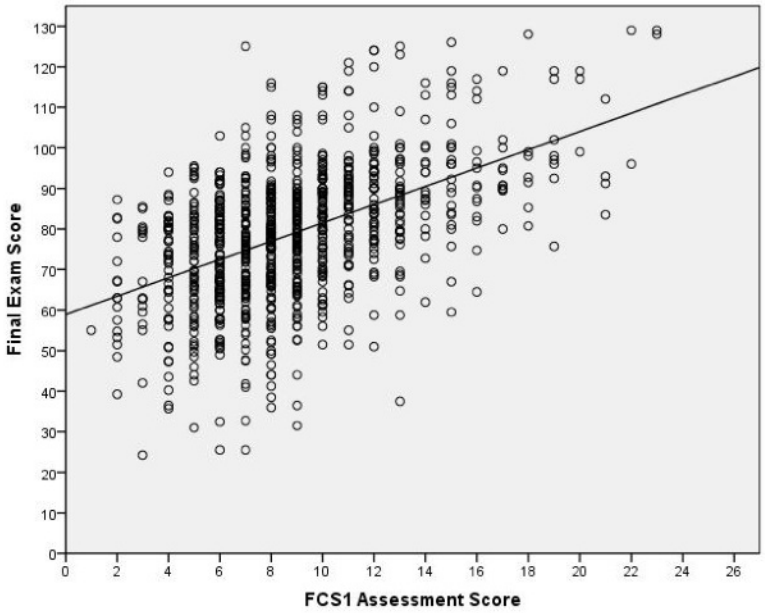
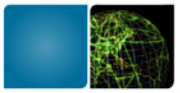
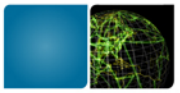


Figure 9: Scatterplot of Scores for Correlation of FCS1 Assessment Score and CS1 Final Exam Score

Performance on FCS1

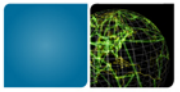

- The majority of students did not pass.
  - The average score on the pseudo-code test was 33.78%.
  - The average score was 48.61% on the “native” language test.


We don't know *why* programming is so hard

- Specifying behavior for an alien agent (Resnick's MultiLogo).
  - We can specify instructions for humans (Pane, Commonsense Computing)
- Students are overwhelmed (Clancy & Linn, 1990):
  - "I don't know where to start."
  - "You've taught me so many details, I don't know which ones to use."
- Nothing much is changing (Scratch work from Technion, 2011)

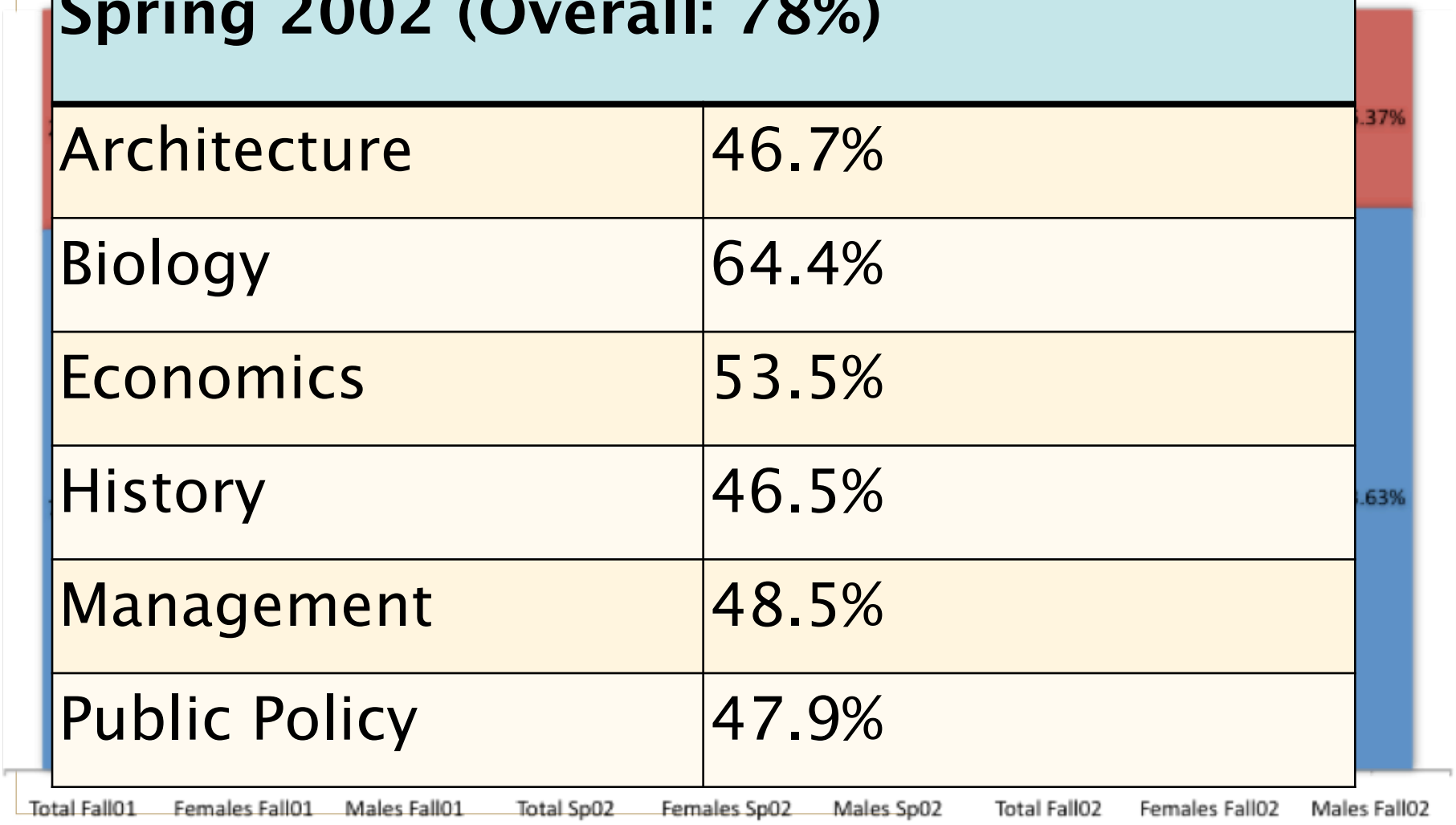
Story #1: Context Matters


- *Fall 1999*:
  All students at Georgia Tech must take a course in computer science.
  - Considered part of General Education, like mathematics, social science, humanities…
- 1999-2003: Only one course met the requirement.
  - Shackelford's pseudocode approach in 1999
  - Later Scheme: How to Design Programs (MIT Press)

One-class CS1: Pass (A, B, or C) vs. WDF (Withdrawal, D or F)

Success Rates in CS1 from Fall 1999 to Spring 2002 (Overall: 78%)	
Architecture	46.7%
Biology	64.4%
Economics	53.5%
History	46.5%
Management	48.5%
Public Policy	47.9%

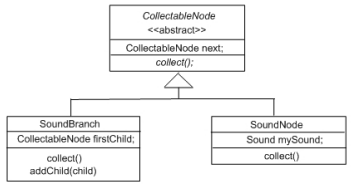


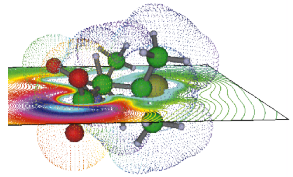
Contextualized Computing Education

- What's going on?
  - Research results: Computing is "tedious, boring, irrelevant"
- Since Spring 2003, Georgia Tech teaches three introductory CS courses.
  - Based on Margolis and Fisher's "alternative paths"
- Each course introduces computing using a context (examples, homework assignments, lecture discussion) relevant to majors.
  - Make computing relevant by teaching it in terms of what computers are good for (from the students' perspective)

Our Three CS1's Today

- CS1301/1321 *Introduction to Computing* Traditional CS1 for our CS majors and Science majors (math, physics, psychology, etc.). Now, uses robots.
- CS1371 *Computing for Engineers* CS1 for Engineers. Same topics as CS1301, but using MATLAB with Engineering problems.
- CS1315 *Introduction to Media Computation* for Architecture, Management, and Liberal Arts students.

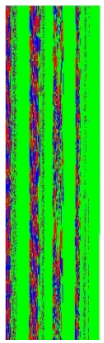




Media Computation: Teaching in a Relevant Context

- Presenting CS topics with media projects and examples
  - Iteration as creating negative and grayscale images
  - Indexing in a range as removing redeye
  - Algorithms for blending both images and sounds
  - Linked lists as song fragments woven to make music
  - Information encodings as sound visualizations



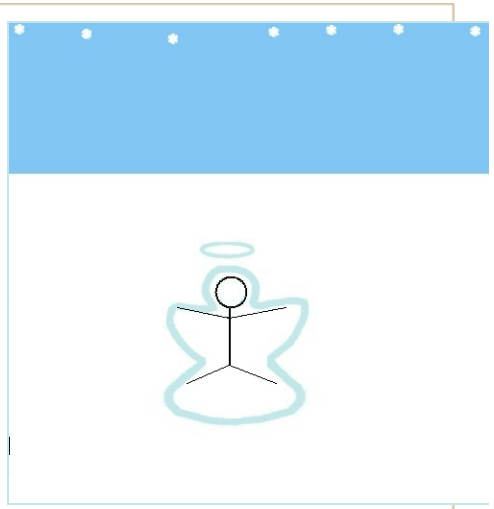



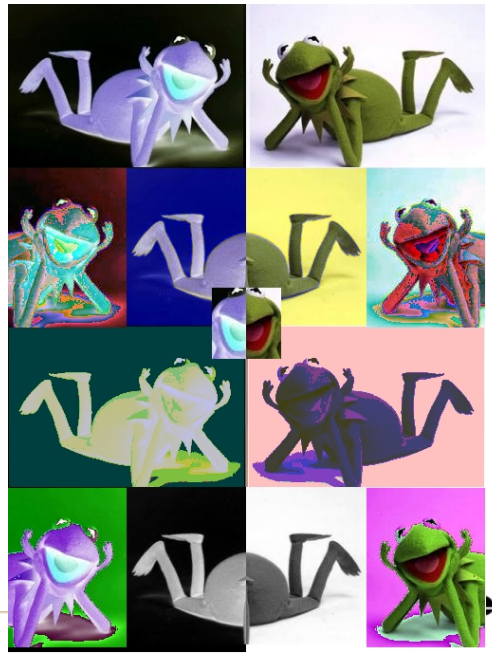
```
def clearRed(picture):
  for pixel in getPixels(picture):
    setRed(pixel,0)
```

```
def greyscale(picture):
  for p in getPixels(picture):
    redness=getRed(p)
    greenness=getGreen(p)
    blueness=getBlue(p)
    luminance=(redness+blueness+greenness)/3
    setColor(p, makeColor(luminance,luminance,luminance))
```

```
def negative(picture):
  for px in getPixels(picture):
    red=getRed(px)
    green=getGreen(px)
    blue=getBlue(px)
    negColor=makeColor(255-red,255-green,255-blue)
    setColor(px,negColor)
```

Open-ended, contextualized homework in Media Computation CS1 & CS2





Sound collage

Linked list as canon

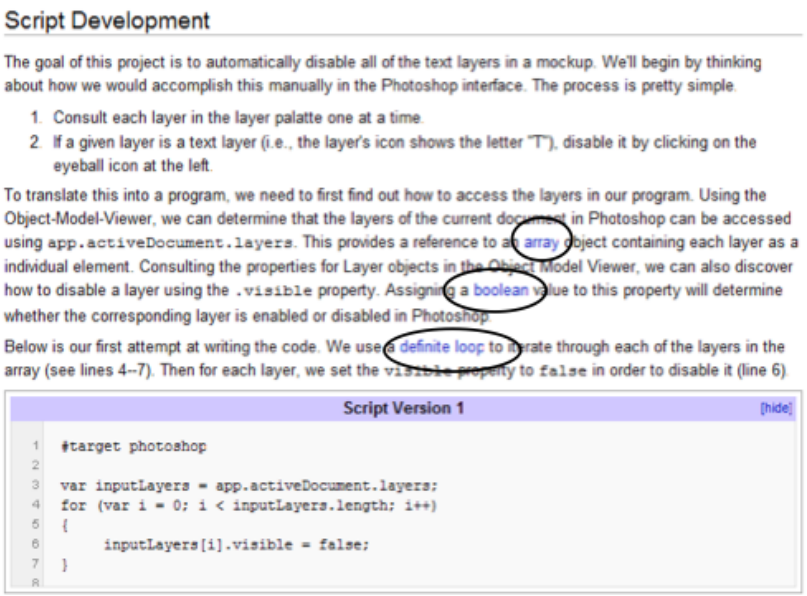
Results:CS1"Media Computation"

Change in Success rates in CS1 "Media Computation" from Spring 2003 to Fall 2005 (Overall 85%)		
Architecture	*46.7%*	85.7%
Biology	*64.4%*	90.4%
Economics	*54.5%*	92.0%
History	*46.5%*	67.6%
Management	*48.5%*	87.8%
Public Policy	*47.9%*	85.4%

WDF
Pass

Other examples where context helps

- Brian Dorn's 2010 thesis on teaching graphics designers computer science.
  - By "hiding" CS lessons in their case studies.
- Leahy et al. 2008 study of teaching computer organization with Gameboys.
  - No learning difference, big motivation difference and time-on-task



Script Development

The goal of this project is to automatically disable all of the text layers in a mockup. We'll begin by thinking about how we would accomplish this manually in the Photoshop interface. The process is pretty simple.

1. Consult each layer in the layer palatte one at a time.
2. If a given layer is a text layer (i.e., the layer's icon shows the letter "T"), disable it by clicking on the eyeball icon at the left.

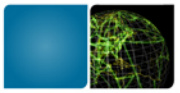
To translate this into a program, we need to first find out how to access the layers in our program. Using the Object-Model-Viewer, we can determine that the layers of the current document in Photoshop can be accessed using `app.activeDocument.layers`. This provides a reference to an array object containing each layer as a individual element. Consulting the properties for Layer objects in the Object Model Viewer, we can also discover how to disable a layer using the `.visible` property. Assigning a boolean value to this property will determine whether the corresponding layer is enabled or disabled in Photoshop.

Below is our first attempt at writing the code. We use a definite loop to iterate through each of the layers in the array (see lines 4--7). Then for each layer, we set the `visible` property to `false` in order to disable it (line 6).

Script Version 1 [hide]

```
1  #target photoshop
2
3  var inputLayers = app.activeDocument.layers;
4  for (var i = 0; i < inputLayers.length; i++)
5  {
6      inputLayers[i].visible = false;
7  }
8
```

Georgia Tech College of Computing


Story #2: Collaboration helps (sometimes)

- Based on earlier work with Jennifer Turns (2000).
- We showed that “anchored collaboration” resulted in longer, on-topic discussion threads.
  - Compared with course Usenet newsgroups.
- What if anyone could create an “anchor” or a “discussion space”?

Using the first Wiki for undergraduate learning

Sandbox - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Search Favorites Media

Address http://swiki.cc.gatech.edu:8080/edtech/520

view edit attach history home changes

Sandbox

Here's a place to play with Swikis.

A Sample Page

Naomi was here.

Let's talk about ITICSE 2001.

Mark Guzdial was here.

Mike Eisenberg was here.

File Edit View Go Bookmarks Communicator Help

Netscape: Edit Sandbox

Back Forward Reload Home Search Netscape Images Print Security Shop Stop

Location: http://swiki.cc.gatech.edu:8080/edtech/520.edit

What's Related

CS2340 CoWeb CS4660 Educatio AccessAtlanta - Mark Guzdial In Collaborative S Computer Music

view edit attach history home changes search help

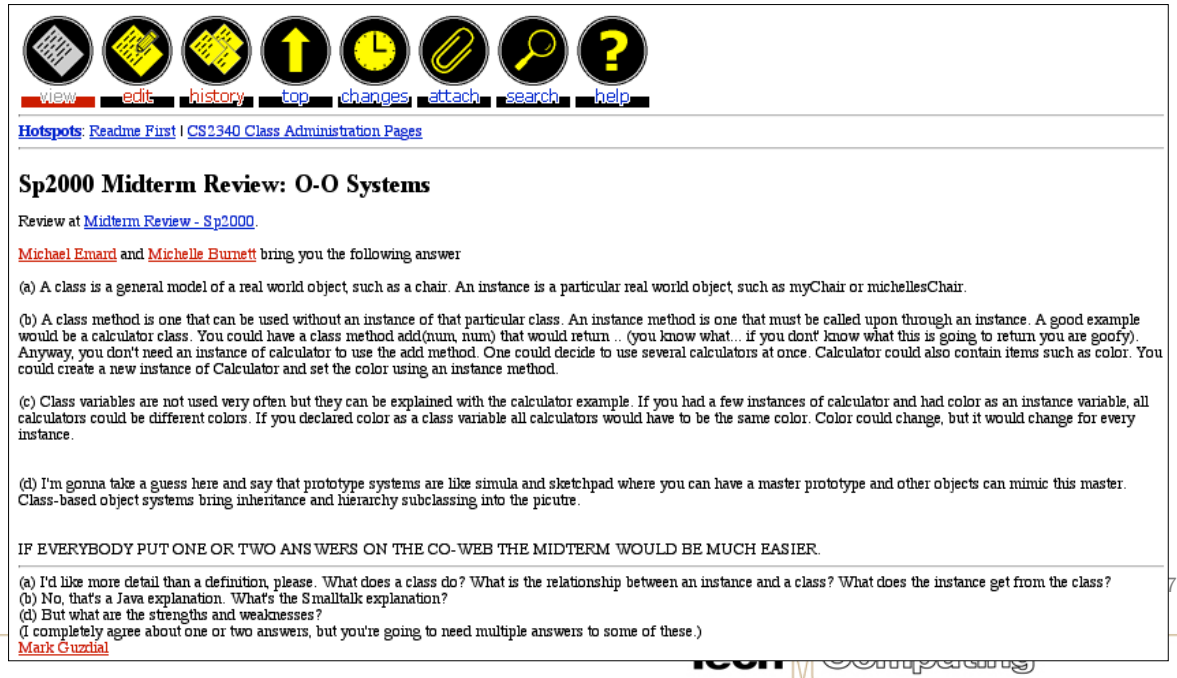
Title: Sandbox

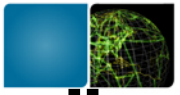
Last edited: 10:31:13 pm on 5 November 2001 by guzdial2.cc.gatech.edu

```
Here's a place to play with Swikis.

<hr>

*Naomi* was here.

Let's talk about *ITICSE 2001*.

*Mark Guzdial* was here.

*Mike Eisenberg* was here.

*+ants.jpg+*

What do you call a drunk rhinocerous?
A wino Rhino.  --JimDavies

*Elliot Soloway* was here.
```

Uses of the CoWeb in CS Classes

- Galleries of student work
- "Organizational memory" for teams (and graders)
- Midterm and final exam reviews
- Glossaries
- Case libraries



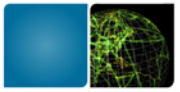

Role of the Homework "Galleries"

Q: What do you think about the homework galleries on the CoWeb?

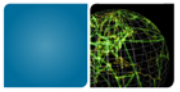
Student 4: It's nice to see other people, like what they did with it... And there is no better feeling than getting something done and knowing that you've done it right.

Student 3: I don't ever look at it [the homework gallery] until after I'm done. I have a thing about not wanting to copy someone else's ideas. I just wish I had more time to play around with that and make neat effects. But JES [IDE created for this class] ***will be on my computer forever***, so... the nice thing about this class is that you could go as deep into the homework as you wanted. So, I'd turn it in, and then ***me and my roommate would do more after to see what we could do with it***.

Anecdotes from Engineering and Math


- On a mandatory assignment involving a math class studying results from Engineering students' simulations, 40% of math students accepted a *zero* rather than collaborate with engineers.
- We provided an Equation Editor in the CoWeb for an Engineering and a Math course to facilitate talking about equations. Not a single student even *tried* the Editor.
- Changed the focus of our research: Why not participate?

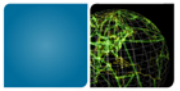

Competition

- Student quotes on “Why didn’t you participate in CoWeb?”

  “1) didn't want to get railed 2) with the curve it is better when your peers do badly”

  “since it is a curved class most people don’t want others to do well”

Note: Students claimed that the course grades were “curved” even when there was none.


Learned helplessness

- Student quotes:

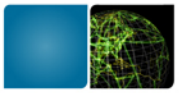
  "I haven't posted about questions because I am confident that my answers are wrong."

  "I thought I was the only one having problem understanding what was asked in the exam."

  "Who am I to post answers?"

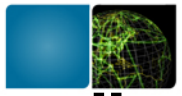
  "The overall environment for [this class] isn't a very help-oriented environment."

Bottom line: Collaboration may not "just work" in Engineering/ Math/CS – not without an explicit focus to make it work.

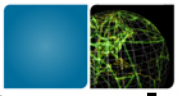

Story #3: Restructuring Instruction

- Educational psychologists really know something about learning & teaching.
- When everyone is demanding your classes, you don't have to sweat it.
- But to teach those that aren't *demanding* to get in, we *do* have to sweat it.

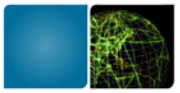

Helping students figure out "how"

- Provide worked examples (Anderson et al., 1984)
  - Label subgoals in worked examples (Catrambone, 1994; 1998)
    - Successful in other domains (e.g., statistics)
    - Hypothesis: Students remember the subgoals, and transfer those.
- Subgoal labels groups steps of a worked example into a meaningful unit
  - Helps students differentiate between structural and incidental information
  - Provide framework for general mental model of process

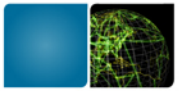

Employing Subgoal Labels in CS Ed

- Used these techniques to teach Android App Inventor to programming novices
- 2 groups (N=40, No App Inventor experience):
  - Original/Conventional (created by Barbara Ericson)
  - Subgoal-labeled
- Materials were identical except for the subgoal labels


Experiment Procedure

- 2 hour-long sessions
- Session 1
  - 5 min – demographic questionnaire
  - 40 min – instructional period for first app
  - 15 min – assessment 1
- Session 2
  - 10 min – assessment 2
  - 25 min – instructional period for second app
  - 25 min – assessment 3
    - 15 minutes to answer questions
    - 10 minutes to make a new (third) app to specification


Example of Written Materials

Subgoal

Define Variables from Built-in

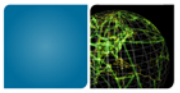
- Click on "Built-In" and "Definition" and pull out a *def variable.*
- Click on the "variable" and replace it with "fortuneList". This creates a variable called "fortuneList".
- Click on "Lists" and drag out a *call make a list*
- Click on "Text" and drag out a *text text* block and drop it next to "item". Click on the rightmost "text" and replace it with your first fortune.

Handle Events from My Blocks

- Click on "My Blocks" and "Button1".
- Drag out a *when Button1.Click*.

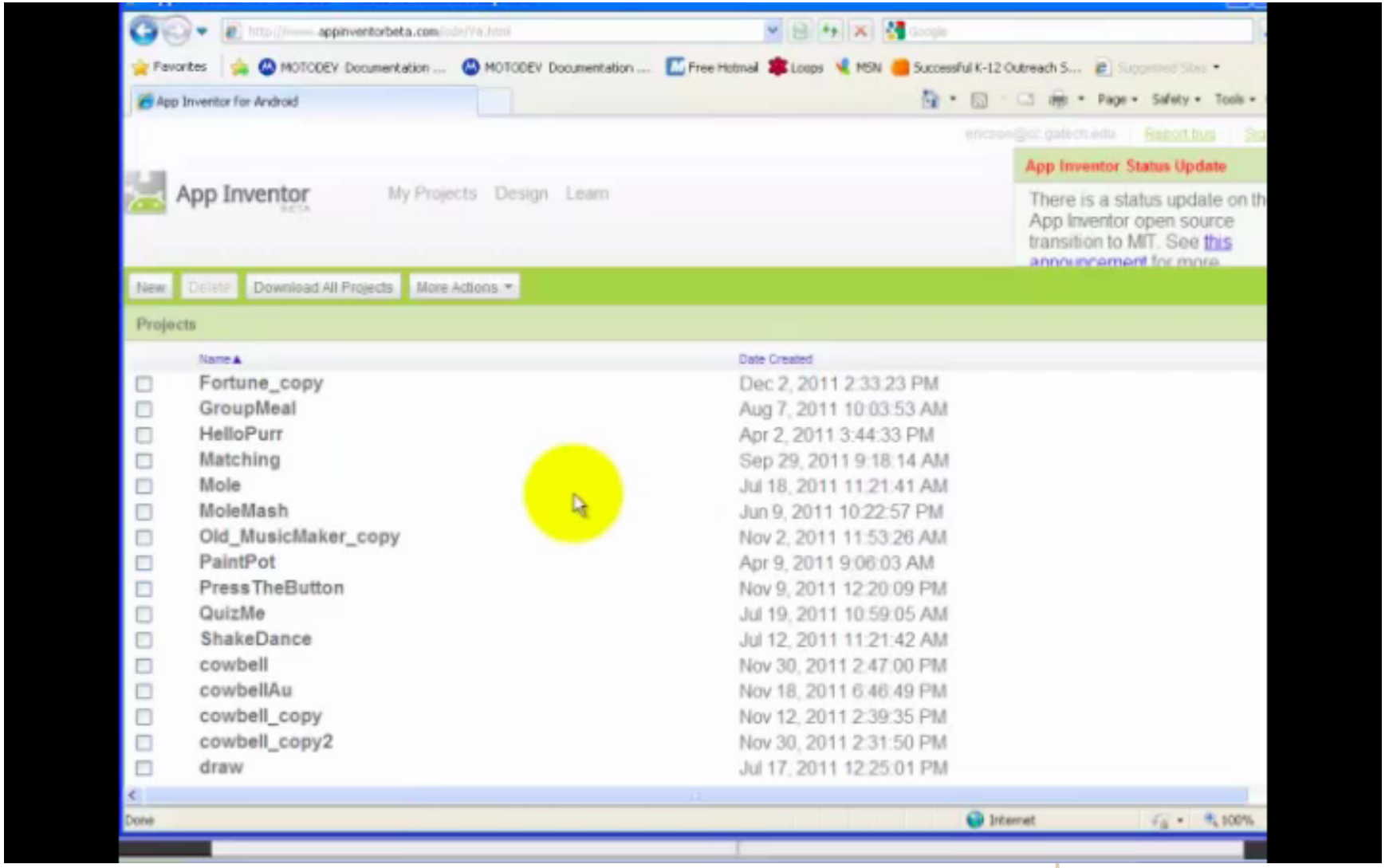
Non-subgoal

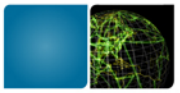
- Click on "Built-In" and "Definition" and pull out a *def variable.*
- Click on the "variable" and replace it with "fortuneList". This creates a variable called "fortuneList".
- Click on "Lists" and drag out a *call make a list*
- Click on "Text" and drag out a *text text* block and drop it next to "item".
- Click on the rightmost "text" and replace it with your first fortune.
- Click on "My Blocks" and "Button1".
- Drag out a *when Button1.Click*.


Original/Conventional Video

Video with Subgoals

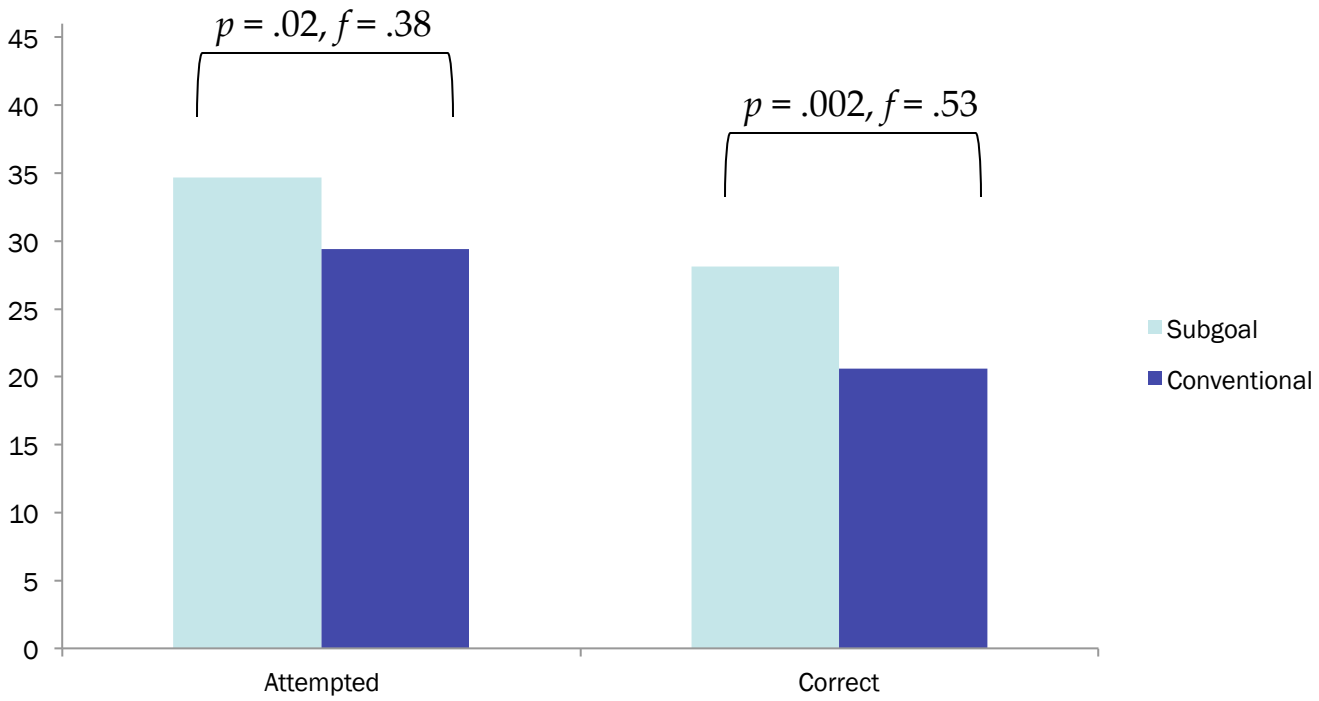


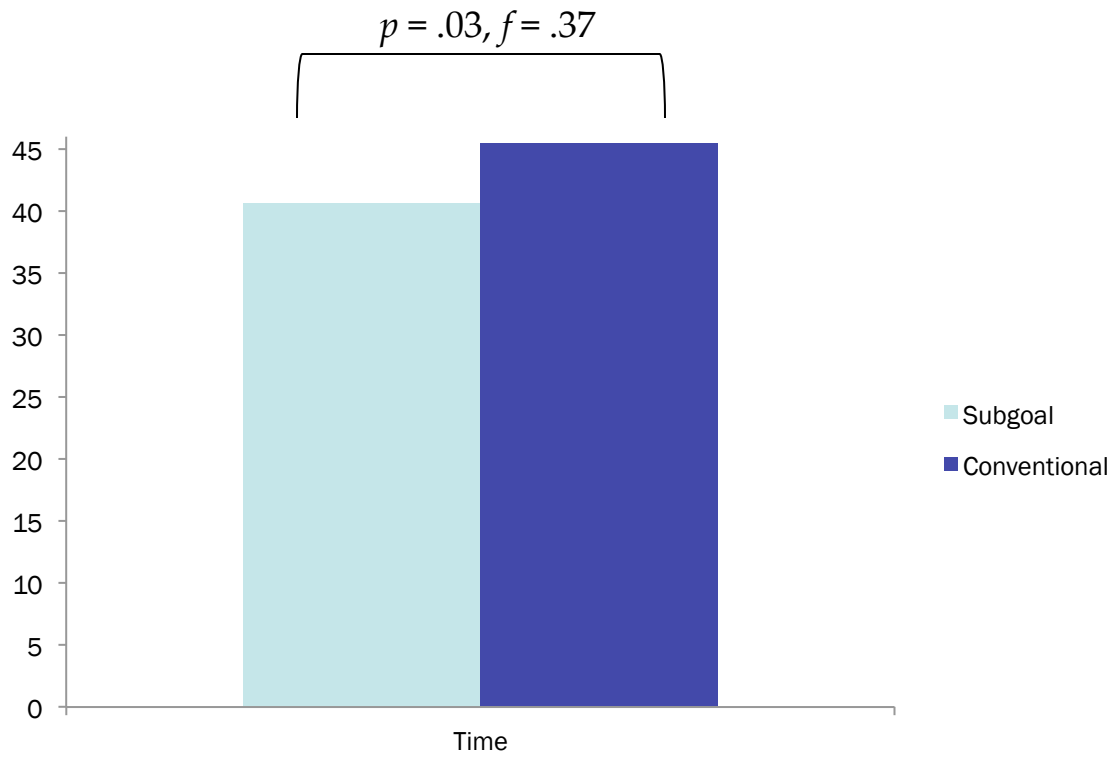

Scoring

- Answers scored on 2 dimensions
  - Subgoals ATTEMPTED
  - Subgoals CORRECT
- 46 subgoals across the 3 assessments
- Interrater reliability
  - ICC(A) = .97, Cronbach's alpha = .98, *r* = .96

Results: Overall



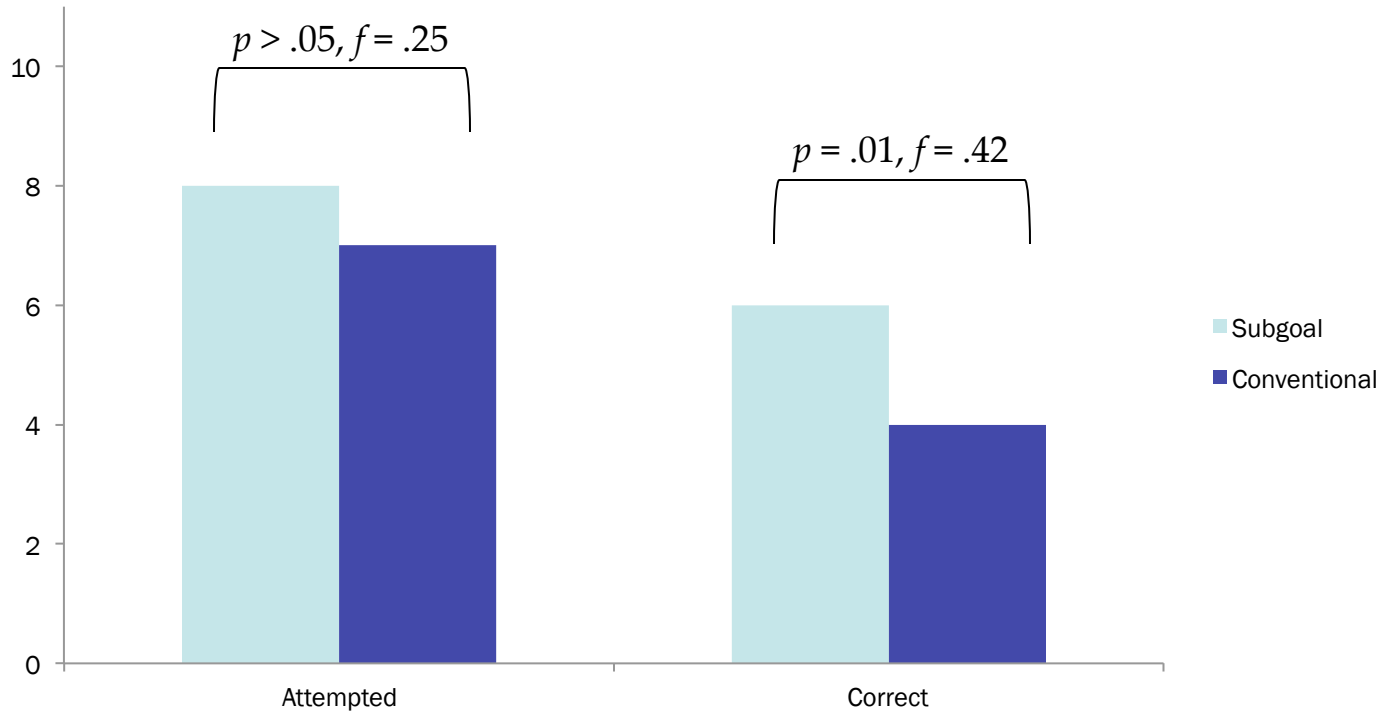
Results: Time



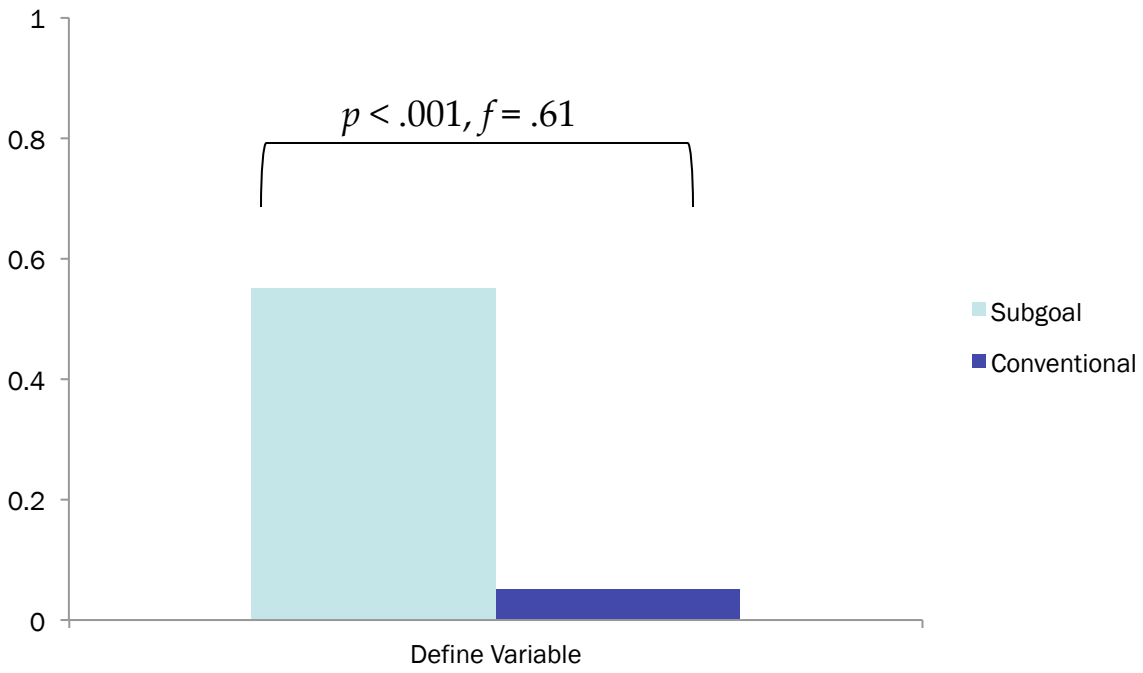
- *r* between time and correct = .06

What this means: Subgoal group was faster, but faster didn't mean that they did worse.

Results: Retention Assessment

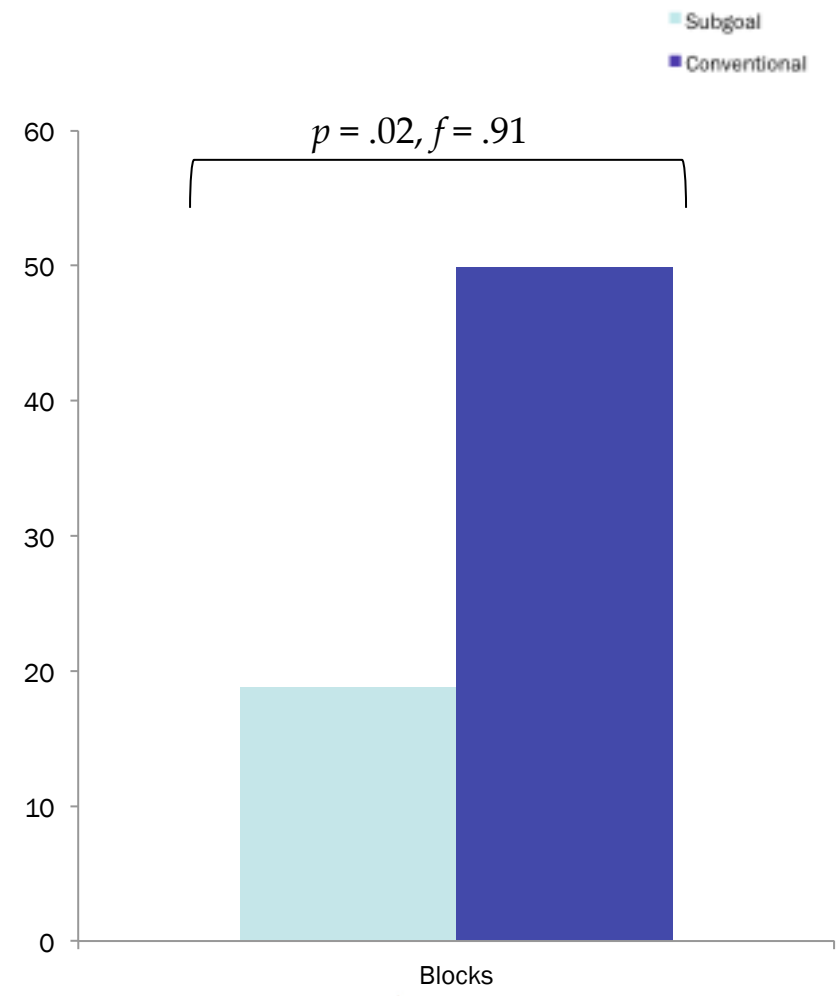


Results: Define Variable Step in Transfer Task



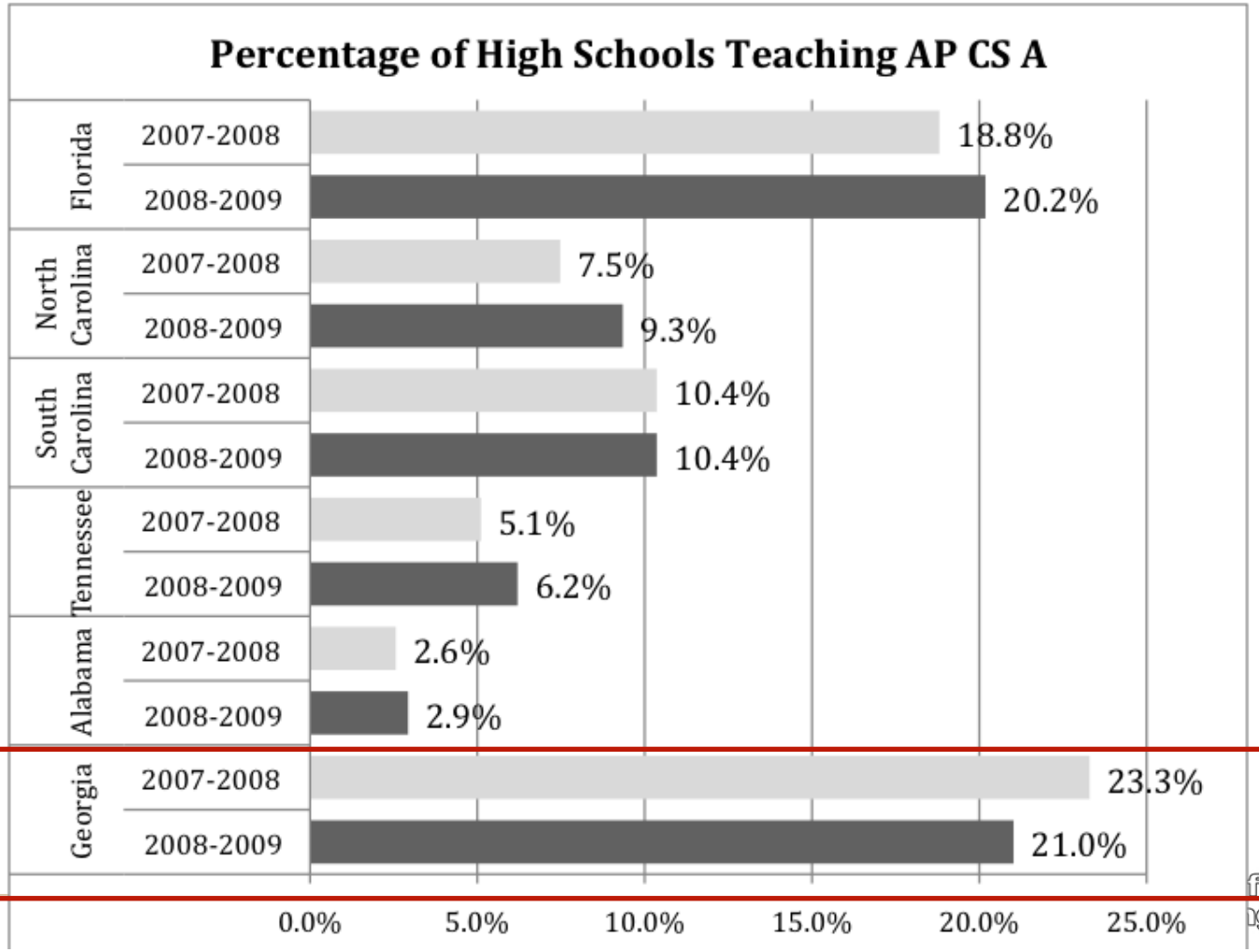
Results: Less thrashing

- Side observation: Less thrashing.
  - Participants in the subgoal group were less likely to drag out blocks while working through assessment tasks ($p < 0.02$)
- r between correctness and #blocks = -.349



Story #4: Fit into their lives

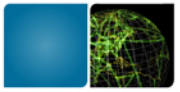
- Where are we going to get enough high school CS teachers?



Teachers feel a need for more training

- *[Becky]: "I struggle with giving everyone the material and being able to explain it to everyone… I struggle with how to be creative with the programming. I have a problem with trying to make the programs have meaning to them… It is hard to teach. It's hard knowing how to teach it, how to give it to them… It's hard to explain. When I look at kid's codes, they think I should know it… They think that I should know it as soon as I look at it. For the longest time I thought I should, but I don't have to. I have to study it just like they do.* ***So, I would like some training.****"*

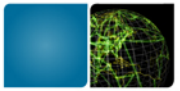
From Lijun Ni's 2011 thesis on CS teacher identity


Easier with Support

- Confidence: More confident in teaching Math

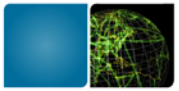
  [John]: "I still think I'm a better Math teacher, just because I've had so much support. Whenever I have problems, I can talk with the people that I work with, most of who have taught for many years in Math… With Computer Science, I've got nobody to talk to."


They may find CS inaccessible

- *[May]: "I think,* **computer science is more for really, really smart people**. *I'm not saying I'm smart, but I'm thinking that if I have to go take this Computer Science degree, that it's going to be really hard, because it's going to ask a lot of programming questions, syntax questions. I think computer science is a much higher level…* **When I say computing, I think of computing as being able to operate the computer**, *… I believe that most students can successfully take and complete Computing in the Modern World, but* **it takes a little higher level of intelligence to complete the Introduction to Programming**

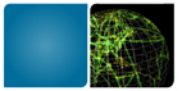
How do we teach working high school teachers?


- Study of adult/professional students in CS classes (i.e., apprenticeship-model).
  - They don't have the time to spend hours in front of the IDE.
  - Lacking background, e.g., in mathematics.
  - They get stymied by small errors.

When Life and Learning Do Not Fit: Challenges of Workload and Communication in Introductory Computer Science Online

KLARA BENDA, Georgia Institute of Technology
AMY BRUCKMAN, Georgia Institute of Technology
MARK GUZDIAL, Georgia Institute of Technology

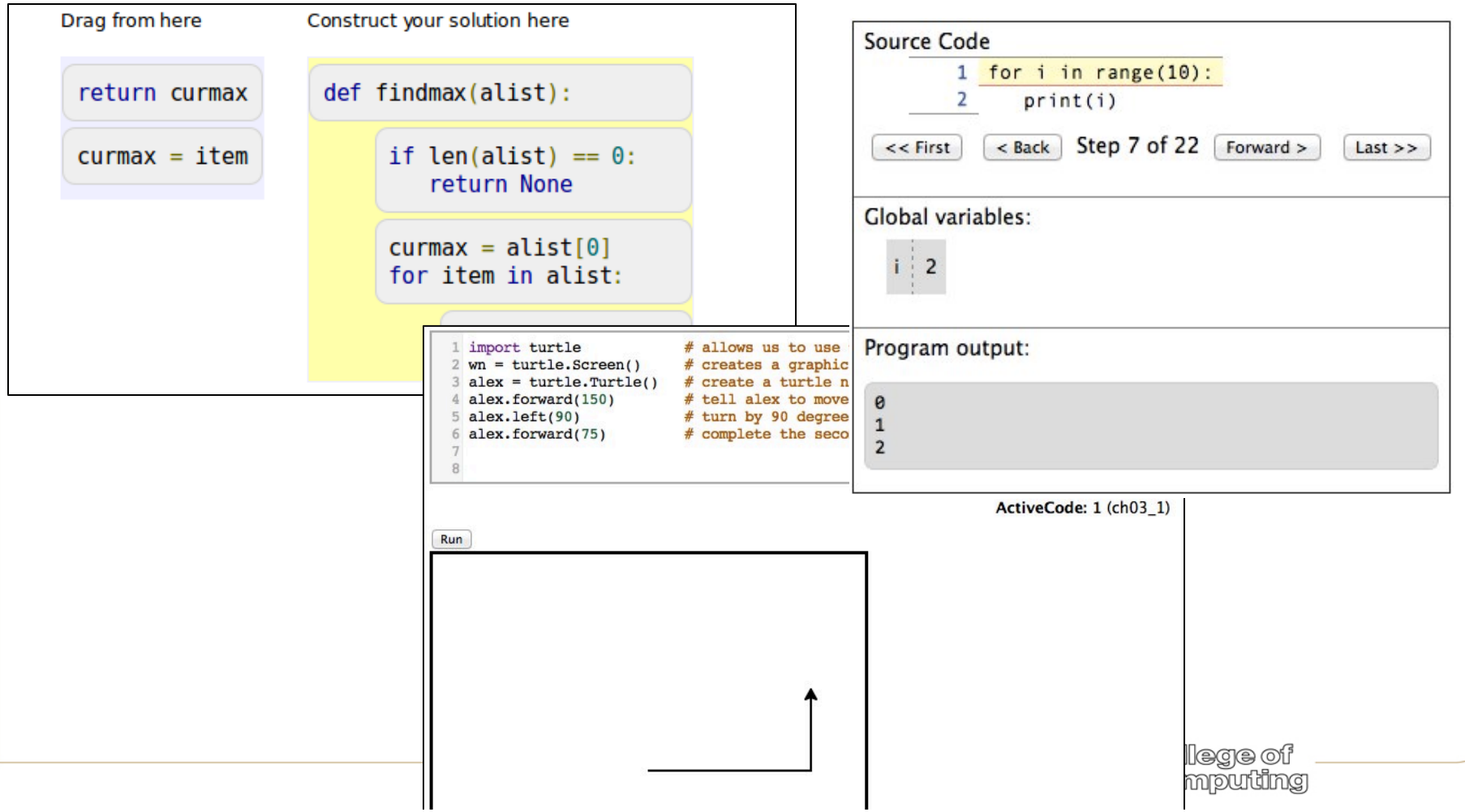

"I had my few afternoon hours that I could work on the stuff, but it all just boiled down to me not having time for my family when I was taking the courses. I think the bottom line was with my family structure, I shouldn't have taken more than one course at once." [...] "sometimes I felt like I wasn't putting enough into one class because I was putting so much into the other class." [...] "Then I had to put more time into the family, because I didn't put in as much as I should have, but I still had to put time in for them."

Andrew - "I said one time that I couldn't get this mathematical problem to work. His response was, "I'm not going to teach you algebra." So if you get one little piece or spacing wrong, it doesn't work."

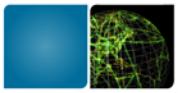
John – "There were times that it would take me hours to find one comma out of place, or find that one something that was wrong, so I didn't mind sticking with it but it just got to the point where I just didn't get it."

Trying to teach CS more Efficiently

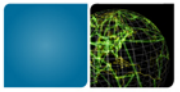
- Using a model of a book, but with live code and Ed Psych principles:



Conclusions


- We want everyone to learn to program, and it's surprisingly hard.
  We don't know why, but we know some things that help and some challenges.
- Story #1: Contexts help.
- Story #2: Collaboration helps, but not always.
- Story #3: Restructing instruction helps.
- Story #4: We need to figure out how to teach CS in ways that fit into peoples lives.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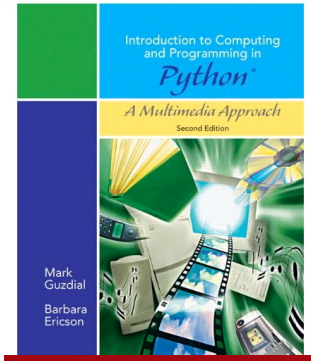

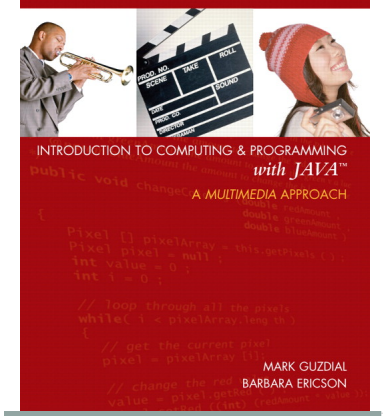

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- http://home.cc.gatech.edu/csl/CSLearning4U

For more on MediaComp approach:

- http://www.mediacomputation.org