Meeting the Needs for a Computationally Literate Society

Mark Guzdial
School of Interactive Computationally

Georgia Tech
I. The first computer scientists set a goal to achieve a **computationally literate society**.
   • Computationally literacy provides the information processing skills needed for modern society.

II. **Challenges** to Achieving a Computationally Literate Society
   • Access and Diversity
   • Unanswered research questions of policymakers

III. **New Kinds** of Computing Education
   • Story #1: Embedding – Contextualized Computing Education.
   • Story #2: Tailoring – Unique Needs of High School CS Teachers.

IV. **A Vision** for Computational Literacy in Support of STEM Learning
### 1961 MIT Sloan School Symposium

**COMPUTERS and the world of the future**

Edited by Martin Greenberger

Nothing amuses more harmlessly than computation, and nothing is often more applicable to real business or speculative inquiries. A thousand stories which the ignorant tell, and believe, are away at once when the computer takes them in his grip.

— Samuel Johnson

### 5

The Computer in the University

<table>
<thead>
<tr>
<th>Speaker</th>
<th>ALAN J. PERLIS</th>
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<tbody>
<tr>
<td></td>
<td>Director of the Computation Center</td>
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<td>Professor of Industrial Management</td>
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Developing students' capacity to interpret information, and then to make, critique and revise claims based on evidence must be a primary goal of education.
Papert, Logo; DiSessa, Boxer
Code is Different

\[ x = x_0 + v_t + \frac{1}{2} a t^2 \]
Code is Temporal & Causal

Researcher: Can you tell me how long it took the rock to get to the ground?
Student B: It would be about one second
R: Okay, where did you get that from?
B: If the acceleration is 30 feet per second per second, then per second it will be going 30 feet per second, then it will just take a little longer for it to get to the ground.
R: Why?
B: Because you have to divide the, to get the average velocity, which is how fast it’s going, and how you can measure how far it’s gone, you have to... let’s see... it will be going, it will be going 15 meters per second. Maybe two seconds, I guess.
R: Why?
B: Because... 1.5 seconds. Because, by the time it’s accelerated the second second, it will be going about 45 feet per second, so it’ll have to be between the first and second second that it hits the ground.
II. Challenges

• Access and Diversity: We aren’t reaching everyone.

• Public policy-makers are asking unanswered research questions
Computing education in US by-the-numbers

- ~25,000 high schools in the United States.
- 3,206 AP Computer Science teachers in the United States.
- American Association of Physics Teachers (AAPT) founded in 1930.
- NCTM founded in 1920
Thanks to Brian Danielak
Policymakers’ Questions

- **US NSF Alliances to Broaden Participation in Computing**
  - “Georgia Computes!”
    - Focus: Activities in middle and high school, with lots of teacher professional development.

- **CAITE**
  - Focus: higher-education pathways focused on community colleges in underserved regions.

- Merged to provide support to US states in improving computing education: Expanded Computing Education Pathways Alliance (ECEP)
Issues from States: Make it a requirement?

• South Carolina: Requires CS for graduation, for over 30 years.
  • But it’s not really CS. Should they change?
    • *Can* we teach CS to *everyone*?

• Research Questions:
  • Can we teach CS to special needs students?
  • What are the challenges of teaching CS to English Language Learners (ELL)?
Issues from States: Invest in K-12 and Teachers

- Utah: Focusing on ages 5-10 CS.
  - Only 129 students took AP CS in 2016, only 16 female.

- Research Questions:
  - How much of CS can we teach to children 5-10?
  - Does teaching CS in early grades lead to long term improved attitudes towards CS?
  - How is the cost difference of scaling CS in elementary school?
  - How do teach teachers CS, without losing them to industry?
Issues in States: URM Differences

- Georgia Computes had significant impact on women and Hispanic AP CS exam-takers.
  - Less impact on Black.
- Most states have lower AP CS participation and pass rates for Black students than Hispanic and female students.
- Why?
Comparing Michigan and Georgia

• Michigan
  • Population: 9.9 million (2015 est)
  • Black - 14.28%
  • Hispanic – 4.9%

• Georgia
  • Population: 10.2 million (2015 est)
  • Black – 31.7%
  • Hispanic – 9.4%
Michigan and Georgia AP CS Exam Takers

Females and Blacks

- Michigan-females
- Michigan-Black
- Georgia-female
- Georgia-Black

<table>
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<tr>
<th>Year</th>
<th>Michigan-Females</th>
<th>Michigan-Black</th>
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<td>2016</td>
<td>464</td>
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New kinds of Computing Education

• Story #1: Teach Computing in Context
  • Computing education can be successfully embedded in learning that students care about.

• Story #2: Teaching Computing to meet Needs
  • Computing education should be tailored because not everyone will be a software engineer.
Story #1: The Role of Context

- **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.

- Overall pass rate: About 78%
<table>
<thead>
<tr>
<th>Program</th>
<th>Success Rate</th>
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<tbody>
<tr>
<td>Architecture</td>
<td>46.7%</td>
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<tr>
<td>Biology</td>
<td>64.4%</td>
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<tr>
<td>Economics</td>
<td>53.5%</td>
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<tr>
<td>History</td>
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<tr>
<td>Management</td>
<td>48.5%</td>
</tr>
<tr>
<td>Public Policy</td>
<td>47.9%</td>
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</table>
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 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)

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))
### Results: “Media Computation”

#### Change in Success rates in CS1 “Media Computation” from Spring 2003 to Fall 2005 (Overall 85%)

<table>
<thead>
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<th>Course</th>
<th>2003 Fall</th>
<th>2004 Spring</th>
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<tr>
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<td>46.7%</td>
<td>85.7%</td>
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<tr>
<td>Biology</td>
<td>64.4%</td>
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<td>Economics</td>
<td>54.5%</td>
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<td>History</td>
<td>46.5%</td>
<td>67.6%</td>
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<td>Management</td>
<td>48.5%</td>
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<tr>
<td>Public Policy</td>
<td>47.9%</td>
<td>85.4%</td>
</tr>
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</table>
Eccles (1983) model of achievement-related choices

- Cultural Milieu
  1. Gender role stereotypes
  2. Cultural stereotypes of subject matter and occupational characteristics

- Child's Perception of...
  1. Socializer's beliefs, expectations, attitudes, and behaviors
  2. Gender roles
  3. Activity stereotypes

- Child's Goals and General Self-Schemas
  1. Self-schemata
  2. Short-term goals
  3. Long-term goals
  4. Ideal self
  5. Self-concepts of one's abilities
  6. Perceptions of task demands

- Cultural Milieu
  1. Gender role stereotypes
  2. Cultural stereotypes of subject matter and occupational characteristics

- Socializer's Beliefs and Behaviors

- Differential Aptitudes of Child

- Previous Achievement-Related Experiences

- Children's Interpretations of Experience
  1. Causal attributions
  2. Locus of control

- Child's Affective Reactions and Memories

- Expectation of Success

- Achievement-Related Choices and Performance

- Subjective Task Value
  1. Interest-enjoyment value
  2. Utility Value
  3. Cost
Voices from Media Computation Students

• “I just wish I had more time to play around with that and make neat effects. But JES [IDE for class] will be on my computer forever, so... that’s 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.”

• “I dreaded CS, but ALL of the topics thus far have been applicable to my future career (& personal) plans—there isn't anything I don't like about this class!!!
Survey One Year Later

• 19% of respondents had programmed since class ended

"Did the class change how you interact with computers?"
• 80% say “Yes”

• “Definitely makes me think of what is going on behind the scenes of such programs like Photoshop and Illustrator.”

• 'I understand technological concepts more easily now; I am more willing and able to experience new things with computers now’
Constructing an imaginary world

- The core of the community of practice (Lave & Wenger, 1991) for liberal arts, business, and design/architecture students does not include programming.
- We are constructing a future world.
- We “imagineer” an inauthentic legitimate peripheral participation (Guzdial & Tew, ICER 2006)
  - We tell a story, starting from student expectations, changing reality where necessary.
Story #2: Tailoring for CS Teachers’ Needs

To be successful, CS teachers need a sense of identity

• Where does that sense of identity come from?
  • Confidence in their ability to teach
    • More professional learning: CK and PCK
  • For US CS teachers, from community and role models. (Lijun Ni, 2011)

These are different goals than for software engineers
How do you prepare your students for the AP CS exam?

- And then if I read these [student quizzes], I can see any misconceptions or gaps in what I've done. I get a picture in my mind of where the current class is. Making them do the explaining is new this year. I’m seeing them do a lot better there. I’ll do like little code (assignments) that they’ll write once a week. They have to write it by hand away from the computer, and I’ll read that and write them comments on what they’re doing and help them grade it with a rubric, and also pass them back after I’ve read them for them to grade, too, and have them look at what was catching it or where it didn’t quite get to it.
How do you prepare your students for the AP CS exam?

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A successful CS teacher...

- Writes assignments and comments, rarely code.
- Guides students through rubrics.
- Focus on learning activities (coding away from the computer, explaining).

...is not a Software Developer.
“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....Every day, I’m eating lunch with Math teachers.

With Computer Science, I’ve got nobody to talk to.”

From Lijun Ni’s 2011 thesis on CS teacher identity
DCCE in Georgia

Disciplinary Commons for computationally Educators
Adaptation – High School and University teachers

Goals
1. Creating community
2. Sharing resources and knowledge of how things are taught in other contexts
3. Supporting student recruitment within the high school environment

Work by Briana Morrison, Lijun Ni, Ria Galanos, & Allison Elliott Tew
Building Community

Partnerships Before (PRE) DCCE

Partnerships After (POST) DCCE

Morrison, Ni, & Guzdial, ICER 2012
Improving Recruiting

- 302% increase in number of AP CS students in the year following their participation in the DCCE
  - Year of participation – 122 students enrolled
  - Next year – 491 students pre-registered
  - One teacher 700% increase (3 to 24 students)
Teacher Confidence

“I think DCCE definitely did help [me feel more confident]. I think it was just being a part of a community of teachers that you can actually talk with about teaching. That gives you confidence when you don’t teach it in a vacuum.”
Teaching CS Teachers online

• Can we reach more potential CS teachers online?

  • Emphasizing the skills and knowledge of successful CS teachers

  • Providing support for a sense of community
An Ebook for Teaching CS Teachers
Parsons Problems

csp-5-1-2: The following program uses a turtle to draw a capital L as shown in the picture to the left of this text, but the lines are mixed up. The program should do all necessary set-up: import the turtle module, get the space to draw on, and create the turtle. Remember that the turtle starts off facing east when it is created. The turtle should turn to face south and draw a line that is 150 pixels long and then turn to face east and draw a line that is 75 pixels long. We have added a compass to the picture to indicate the directions north, south, west, and east.

Drag the blocks of statements from the left column to the right column and put them in the right order. Then click on Check Me to see if you are right. You will be told if any of the lines are in the wrong order.
Findings: What do users do in an ebook?

Figure 12. The number of unique users that did each action in Chapter 4

<table>
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<tr>
<th>Label</th>
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<th>Explanation</th>
</tr>
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<tr>
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<td>Dark Blue</td>
<td>Running an activecode</td>
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<td>Red</td>
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<tr>
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<tr>
<td>V</td>
<td>Purple</td>
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</table>

Table 5: Explanation of Labels and Colors for Figure 12

Ericson, Guzdial, & Morrison, ICER 2015
IV. A Vision for Computational Literacy in Support of STEM Learning

• **Embedding**
  • Use computing in authentic contexts and classes

**Vision:**
• Weave computational literacy throughout a curriculum, and track where it appears.

• Professional development to develop computational literacy in pre-service teachers
IV. A Vision for Computational Literacy in Support of STEM Learning

• **Tailoring**
  
  • Like all other forms of literacy, multiple genres, styles, and practices will develop around computing.

**Vision:**

• Invent future computational literacies and communities of practice
• Develop expressive languages and tools that meet needs.
Conclusions

• Computational literacy is critical to meet the needs of a 21st century democracy.

• The challenges are enormous – we are far from universal computational literacy.

• Two lessons from our work:
  1. Providing a context that matches learner interests improves motivation and retention.
  2. Teachers don’t need to be software developers. They need community, confidence, and more learning options beyond apprenticeship.

• Computing education should be embedded and tailored to meet students’ future needs.
Many thanks!

• Colleagues: Barbara Ericson, Tom McKlin, Rick Adrion, Renee Fall, Brad Miller, Ria Galanos, Allison Elliott Tew, Lijun Ni, & Briana Morrison

• Our Funders:
  US National Science Foundation
  • Statewide BPC Alliance: Project “Georgia Computes!” [http://www.gacomputes.org](http://www.gacomputes.org)
  • Expanding computationally Education Pathways Alliance, [http://expandingcomputationally.org](http://expandingcomputationally.org)
  • CCLI and CPATH Grants, and now CE21 and IUSE to produce ebooks

• Georgia’s Department of Education

• GVU Center, and Institute for People and Technology (iPaT) at Georgia Tech
Thank you!

- [http://www.cc.gatech.edu/~mark.guzdial](http://www.cc.gatech.edu/~mark.guzdial)
- Lab: [http://home.cc.gatech.edu/csl](http://home.cc.gatech.edu/csl)
- Media Computation: [http://mediacomputation.org](http://mediacomputation.org)
- Institute for Computing Education at Georgia Tech: [http://coweb.cc.gatech.edu/ice-gt](http://coweb.cc.gatech.edu/ice-gt)
- Expanding Computing Education Pathways (ECEP): [http://ecepalliance.org](http://ecepalliance.org)
Spare Slides
Glitch Game Testers

Betsy DiSalvo and Amy Bruckman

- Engaging African-American Teen Males in CS.

- Hiring them as game-testers, to get them to go below the surface of the technology.

- Of the 33 young men who participated in the program, all completed high school and over half took post-secondary computationally classes.