Code as a metaphor for Computational Thinking

Owen Astrachan

Duke University

http://www.csprinciples.org

Cyber capable [nation|citizenry]

"Our species needs, and deserves, a citizenry with minds wide awake and a basic understanding of how the world works."

Carl Sagan

WE MUST BE THE CHANGE
... we wish to see in the world. ~Ghandi

Cyber capable [nation|citizenry]

"We need a data-literate citizenry, not just a small elite of hackers and policy wonks. And the best way to cultivate that broad-based literacy is not to release in small or measured quantities, but to flood us with data. … But more than this we also need to …involve educators to help provide support and increase people's ability to move up the learning curve."
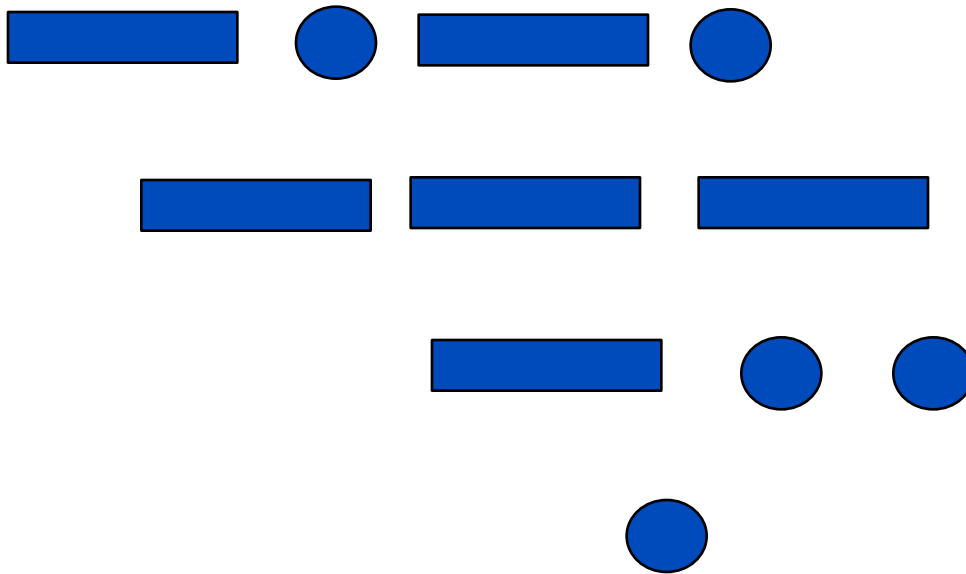
David Eaves `http://bit.ly/b7CP7s`

Where are we going today?

- **Stories to explain computational thinking**
  - ➢ **Personal stories are great, any story is great**

- **Local, Regional, National Initiatives**
  - ➢ **CS Principles and CS10K, IP²**

- **Who is the audience: computational civics**
  - ➢ **What should our senators and president know?**
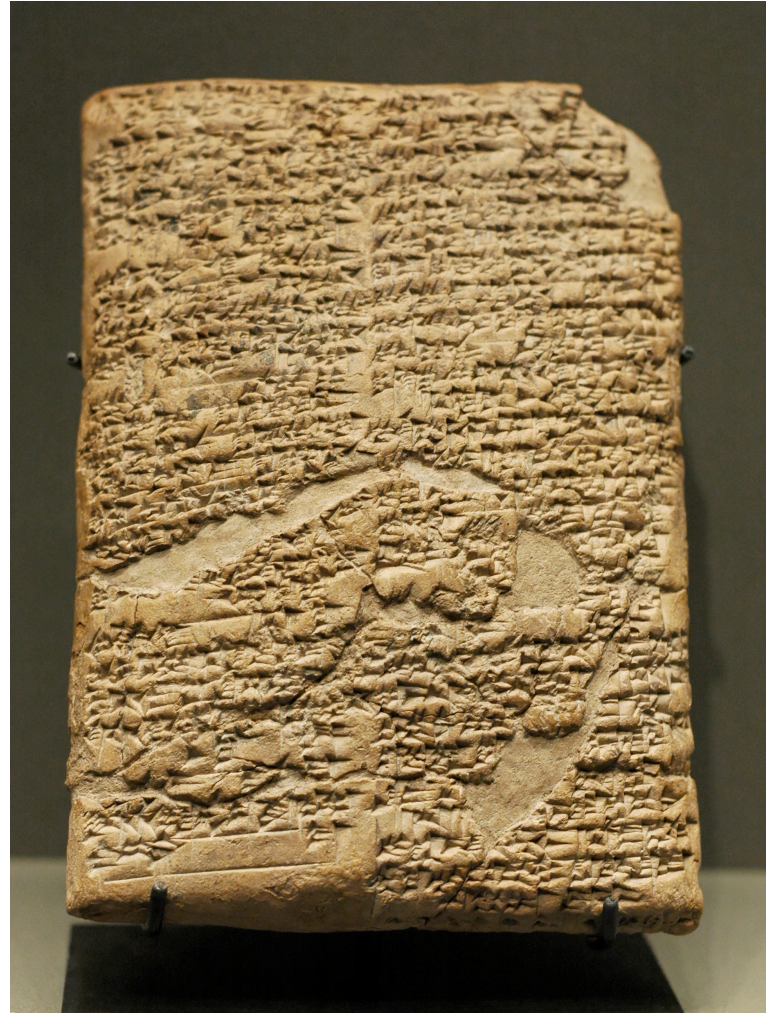
- **How code is a metaphor for all of this**

Code

Code

Code

Code

- **East Coast Code**
- **West Coast Code**

East and West Coast Codes

```
string enz = "gattc";
for(int j=8; j <= 32; j++){
    string splc;
    int spSize = (1 << j)
    for(int k=0; k < spSize; k++){
        splc+= 'c';
    }
    string res = spBh(enz, splc, source)
    cout << res << endl;
}
```

§ 9853. Math skills for secondary school students

(a) Purposes The purposes of this section are—

(1) to provide assistance to State educational agencies and local educational agencies in implementing effective research-based mathematics programs for students in secondary schools, including students with disabilities and students with limited English proficiency;

(2) to improve instruction in mathematics for students in secondary school through the implementation of mathematics programs and the support of comprehensive mathematics initiatives that are based on the best available evidence of effectiveness;

codeforamerica.org

CODE *for* AMERICA

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Engagement in didactic lectures

(a little meta is good for you)

`http://ebooksfreedownload.org/2011/08/indiscrete-thoughts.html`

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Indiscrete Thoughts

Aug 11, 2011 | Comments 0

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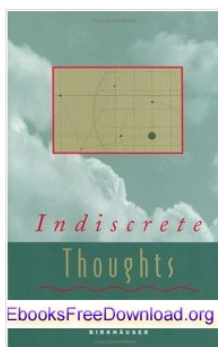
Gian-Carlo Rota, Fabrizio Palombi, quot;Indiscrete Thoughtsquot;

Birkh?user Boston | 1996 | ISBN: 3764338660, 0817638660, 0817647805 | 308 pages | Djvu | 2,1 mb

quot;Indiscrete Thoughtsquot; gives a rare glimpse into a world that has seldom been described, that of science and technology as seen through the eyes of a mathematician. The era covered by this book, 1950 to 1990, was surely one of the golden ages of science and the American university as well.
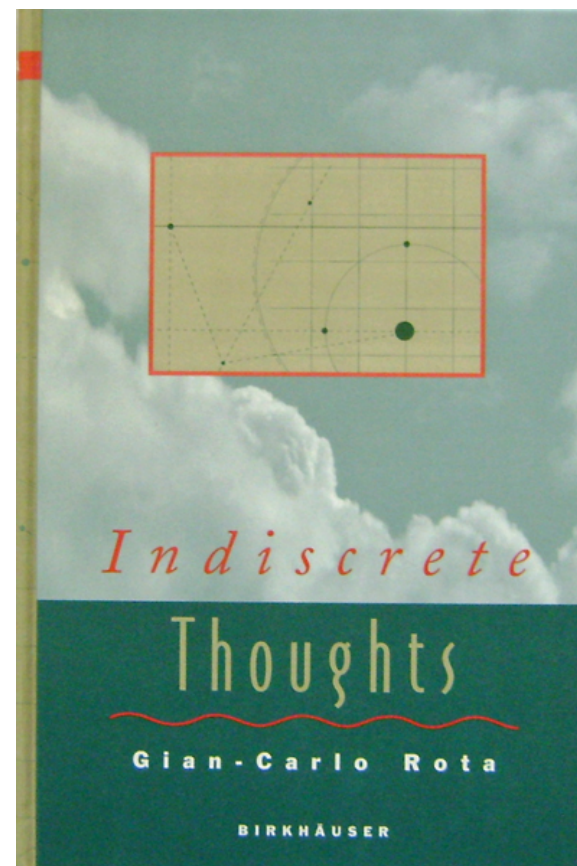
Indiscrete
Thoughts
Gian-Carlo Rota
BIRKHÄUSER

What to take home

- **Lectures should make one main point**
    - ➤ **Theme with variations**

- **Never run overtime**
    - ➤ **One minute overtime can destroy the best lecture**

- **Relate to your audience**
    - ➤ **Everyone wants to hear about themselves**

- **Give them something to take home**
    - ➤ **$2^{10} = 1024$, answer to any question: "it depends"**

Did you ask any good questions?

- **Goal of a job talk?**
  - ➢ **Lose folks after the nth slide?**

- **Goal of a *distinguished* lecture?**
  - ➢ **Motivate work and discussion**

- **Goal of a lecture and a course**
  - ➢ **Part of the educational foundation for students**
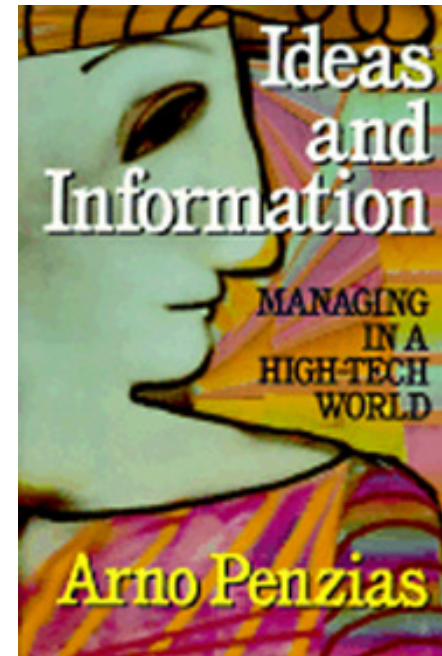
Is there an alternative to the traditional introduction to computer science

Definition of alternative

What should we change?

Change what you teach, toward computational thinking

Change how you teach, toward high-quality, free courses?
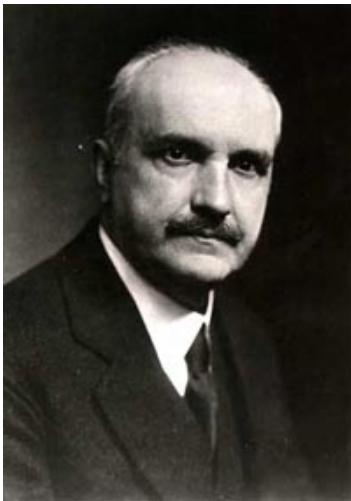
IP^2

CS PRINCIPLES

e-learning...

UDACITY BETA

CS 101: BUILDING A SEARCH ENGINE

Taught by Professor David Evans and Professor Sebastian Thrun
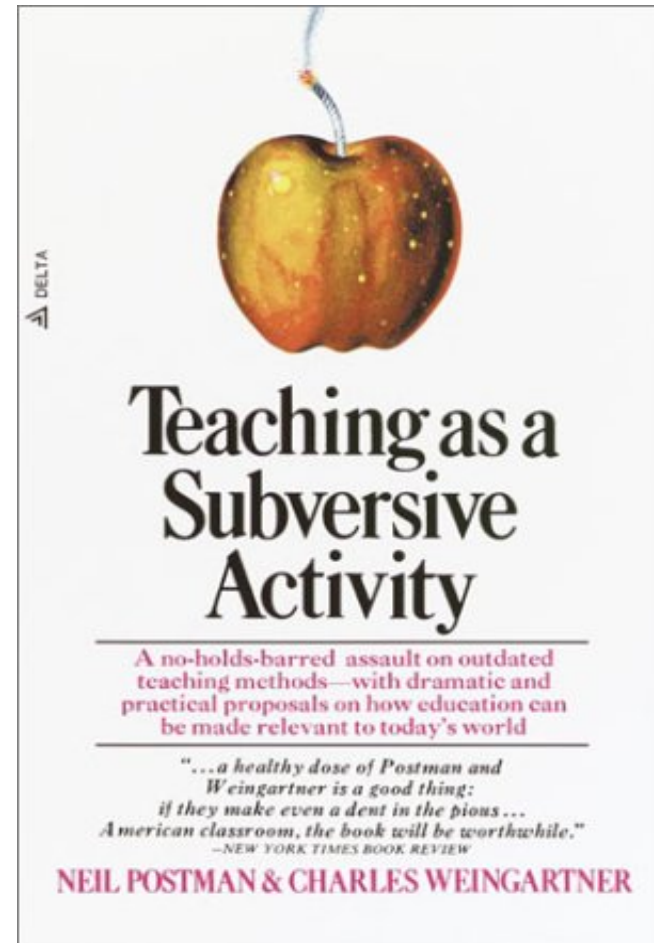
START YOUR COURSE ▶

History and Computer Science

● **Those who cannot remember the past are condemned to repeat it.**

● **Don't know much about history, don't know much about biology, don't know much about a science book**

Teaching as …

English is not history and history is not science and science is not art and art is not music, and art and music are minor subjects and English, history and science major subjects, and a subject is something you 'take' and when you have taken it, you have 'had' it, and if you have 'had' it, you are immune and need not take it again." (The Vaccination Theory of Education?)

DELTA

Teaching as a Subversive Activity

A no-holds-barred assault on outdated teaching methods—with dramatic and practical proposals on how education can be made relevant to today's world

"…a healthy dose of Postman and Weingartner is a good thing: if they make even a dent in the pious… American classroom, the book will be worthwhile." —NEW YORK TIMES BOOK REVIEW

NEIL POSTMAN & CHARLES WEINGARTNER

Top N Questions for CS Educators

- **Mac or PC**
- **Python or Java**
- **Eclipse or Netbeans**
- **Pair or solo**
- **Agile or Waterfall**
- **OO or Old-fashioned**
- **Firefox or Chrome**
- **Ubuntu or Centos**

Does it matter what we talk about to others?

Does it matter what we talk about among ourselves?

[ver-**nak**-*yuh*-ler]

Noun

- **The everyday language spoken by a people as distinguished from the literary language.**

- **The idiom of a particular trade or profession**

  What message do we send our colleagues in other disciplines? What message do we send the general populace? How do we talk to each other and what do we talk about?

ACM Policy Brief

A fundamental understanding of computation and computational or algorithmic thinking is increasingly important to success in the digital age. *Computing education will benefit all students, not just those interested in pursuing computer science or information technology careers.* Computer science develops and extends logical thinking and problem-solving skills. Students who participate in high school computing classes and have previous experience with technology demonstrate improved readiness for post-secondary studies.

http://bit.ly/zxjUVW

Explaining computational thinking to …

Who is the audience for the explanation?

Milking Stool v Neural Queue

- **Engineering, Mathematics, Science**
  - ➤ **Pillars of computer science?**
  - ➤ **Braid of computer science?**
- **Other aspects of CS?**
  - ➤ **Technology and policy**
  - ➤ **Art and visualization**
  - ➤ **Collaborative Filtering**
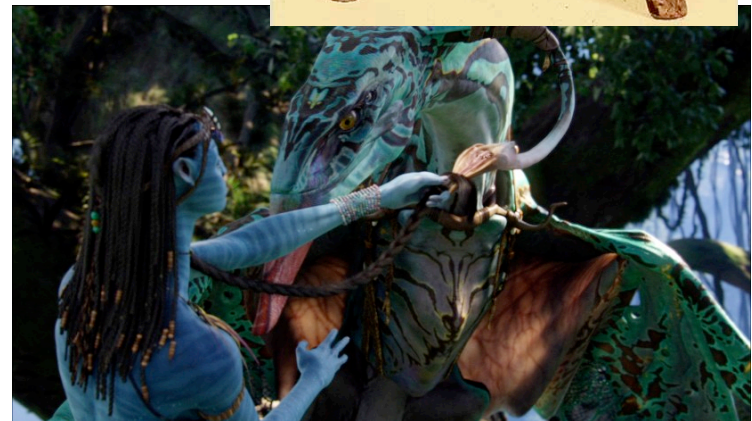
Stories and problems define code

SCHEHERAZADE, DINARZADE, AND THE SULTAN

- **Stories explain code**
  - ➢ **Some of them change often**
- **Rooted in problems**

- **Intended to describe computational thinking**
- **Code is a metaphor, but it better execute**

What is Computational Thinking?

Moral of this tale?

3/18/11 **A former Goldman Sachs computer programmer convicted of stealing source code** from the firm was sentenced on Friday to more than eight years in prison, capping a case that had shone a rare spotlight on the world of lightning-fast computer-driven trading. **Goldman paid him $400,000 a year to write code** for its high-frequency trading business, making him one of the bank's highest-paid programmers

http://nyti.ms/A519aP

2/18/12 At a hearing before the appeals court yesterday, **Marino argued, as he had during the trial, that Aleynikov only took to his new job *open-source code* he had written at Goldman Sachs.** He said the government had tried to expand its reading of the Economic Espionage Act to encompass what his client had done

http://buswk.co/xfSwYy

Jeanette Wing, CACM 2006

Computational thinking builds on the power and limits of computing processes, whether they are executed by a human or by a machine. Computational methods and models give us the courage to solve problems and design systems that no one of us would be capable of tackling alone. Computational thinking confronts the riddle of machine intelligence: What can humans do better than computers, and What can computers do better than humans?

What is Computational Thinking?

- **Potter Stewart, 1984, *Jacobellis v Ohio***
  - ➤ **I shall not today attempt further to define the kinds of material I understand to be embraced within that shorthand description of [computational thinking]; and perhaps I could never succeed in intelligibly doing so. But I know it when I see it,**

A Computational Thinking Story

- **Ladder from 'white' to 'house'**
  - ➤ **White, while, whale, shale, …**
- **I can do that…** *optimally*
  - ➤ **My brother was an English major**
  - ➤ **My ladder is 16, his is 15, how?**
- **The key is sough**
  - ➤ **Voila, 14 words!**

- **Guarantee optimality!**
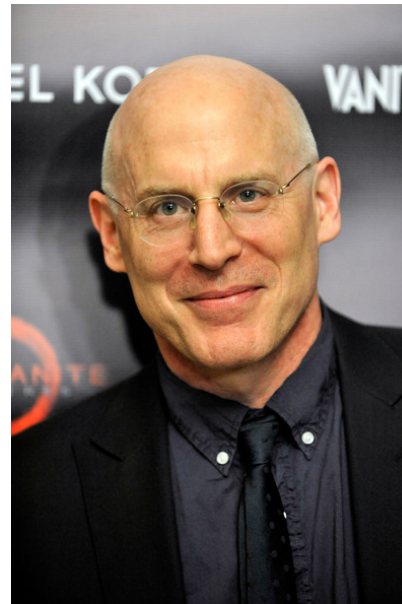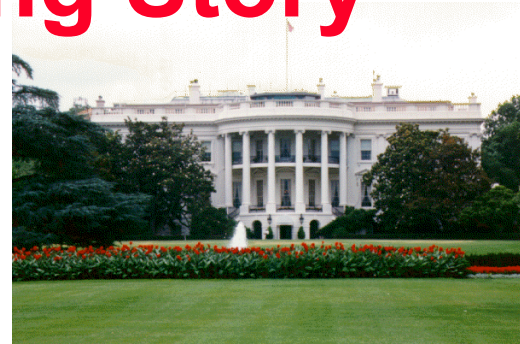
Words and Pictures about code and computational thinking

1001 words is worth more than a picture
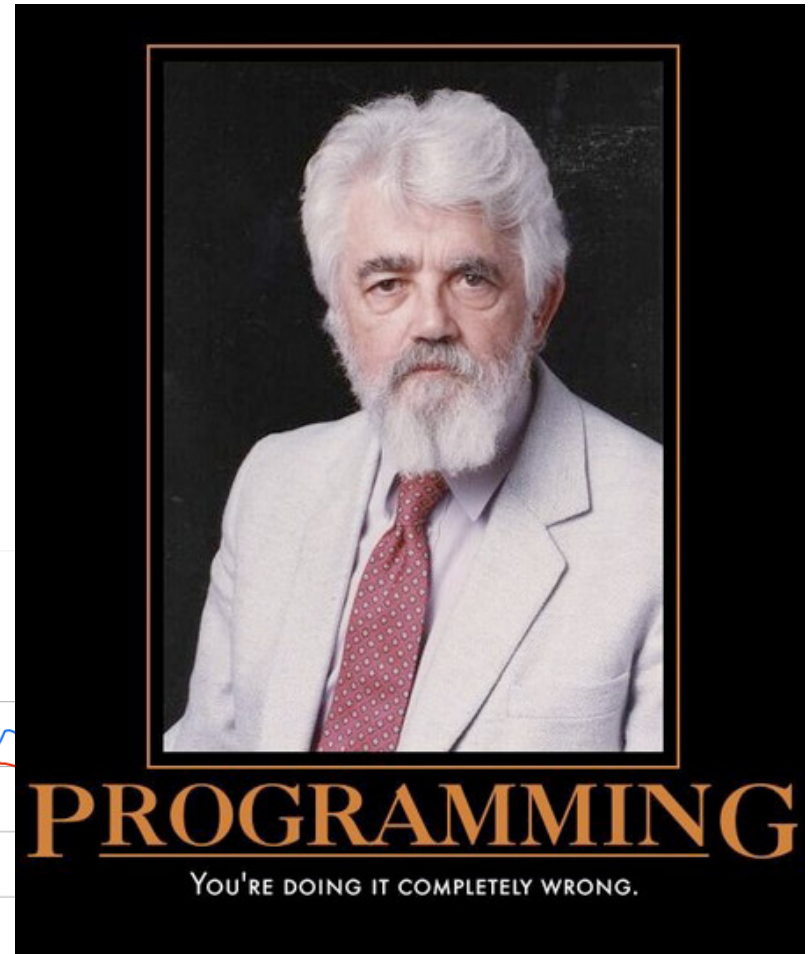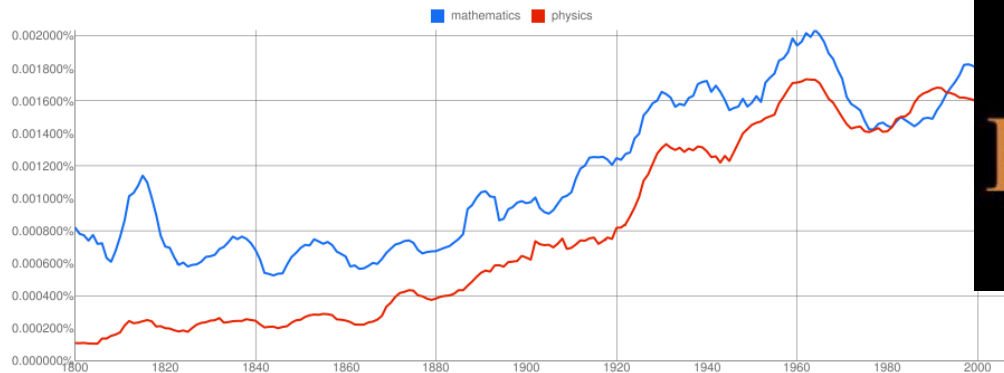
First of three related problems

www.blackplanet.com
437x
www.blackplanet.com/provAKAtive/

Compare | Link
JPEG Image
100x162, 15.8 KB

14 Results

Searched over **2.0907 billion** images in 0.047 seconds.
for file: http://people.cs.vt.edu/ryder/vt_ribbon_gray.gif

These results expire in **72 hours**. Why?

Share a success story!

TinEye is **free** to use for non-commercial purposes.

Download the official TinEye extension for Chrome with right-click functionality!

GIF, 100x143, 2.6 KB

diannemarieee.vox.com
6a00c22529818c8e1d00d09e655706be2b-120si
diannemarieee.vox.com/library/photos/

Compare | Link
GIF Image
120x120, 14.1 KB

Second of three related problems
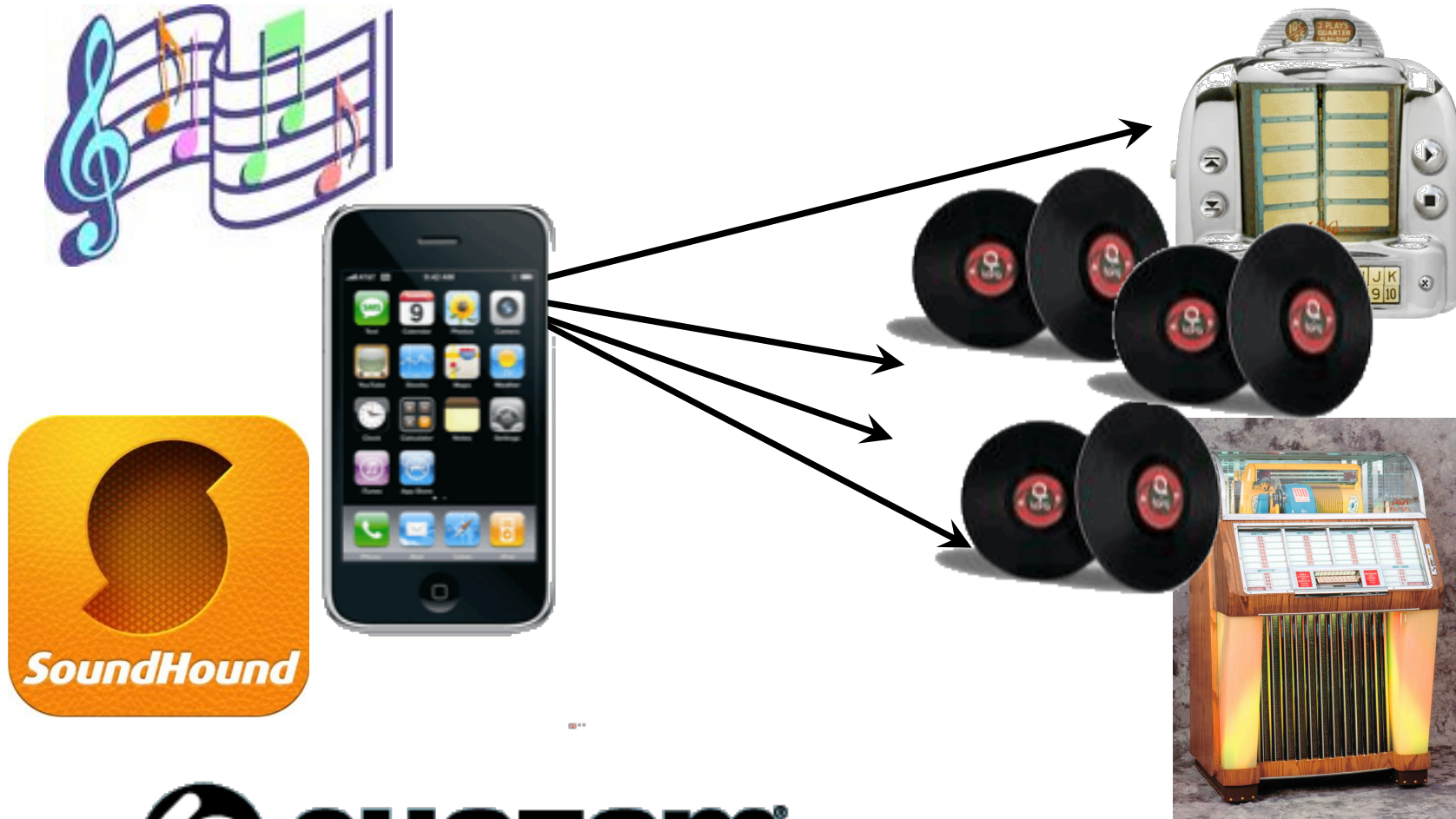
Third of three related problems


```
http://maps.google.com/maps?saddr=Chipotle+Mexican+Grill,
+Erwin+Road,+Durham,+NC&daddr=210+Burruss+Hall,+Blacksburg,
+VA+24060+(Virginia+Tech)
&hl=en&ll=36.613323,-79.93103&spn=1.52117,2.568054&sll=36.614
475,-79.927525&sspn=1.521127,2.568054&geocode=FZx2JQIdrmVL-
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yHWKhbFG1L_DA&oq=chipotle&mra=ls&t=m&z=9
```
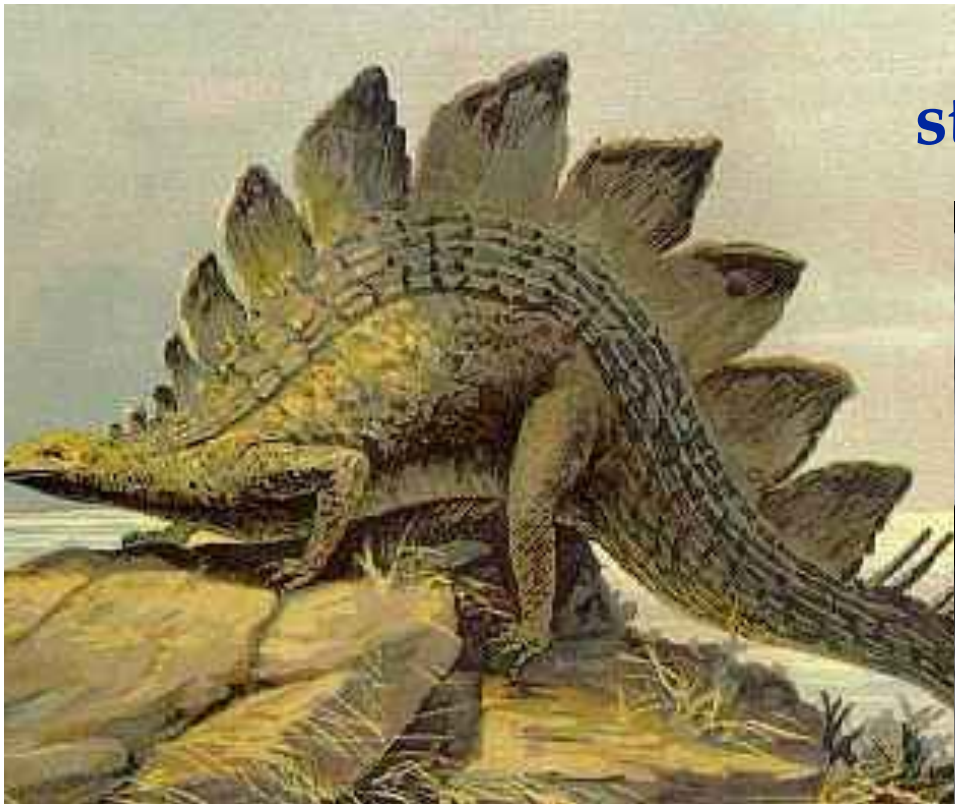
http://g.co/maps/qnbtd
http://bit.ly/yOifjm
http://bit.ly/vtechedu

35

Examining each computational thinking stories in more detail

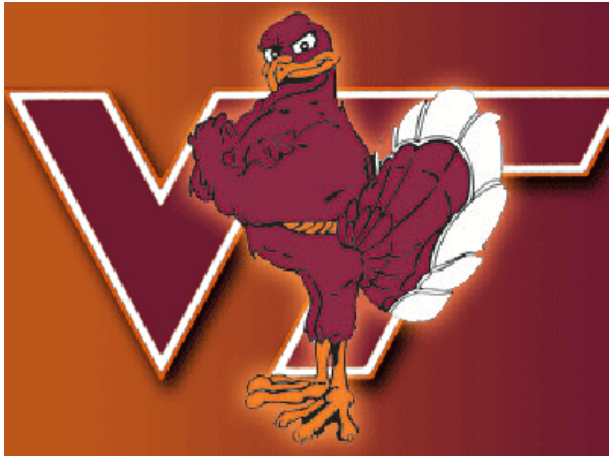## Point-of-view of students in a course

Episode 1: Expansion
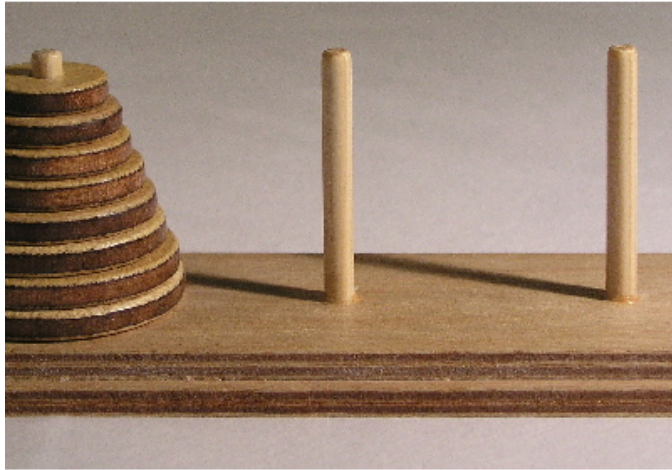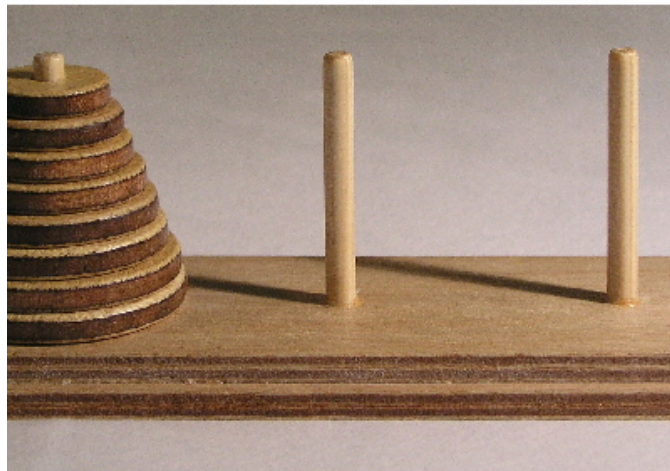

steganos ::= covered
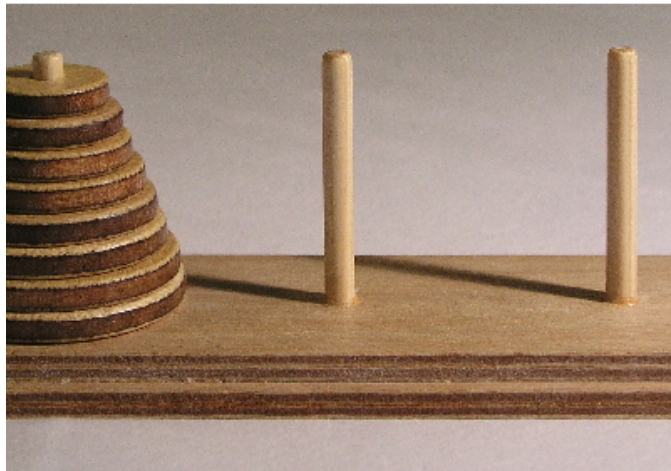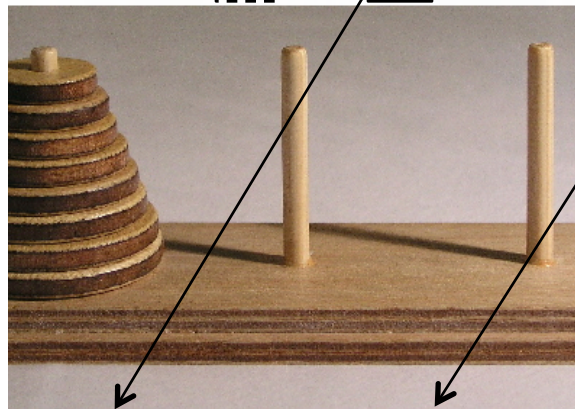

stegos ::= roof

First Equation

Second Equation

Erase LSBs add MSBs
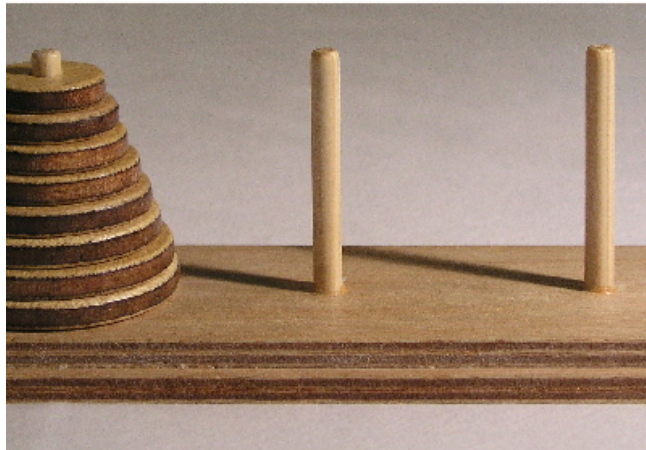

11010101 10101110 01011101   10110111 01011101 11110110

11010110 10101101 01011111

Extracting the image

3 Results

Searched over **1.5728 billion** images in 4.960 sec
for file: **http://www.cs.duke.edu/~ola/images/hanoi-hidden.png**

These results expire in **72 hours**. **Why?**

Post a success story!

PNG, 400x300, 177.9 KB

Hidden Hokie in Blue Devil

334 Results

Searched over **2.0907 billion** images in 0.908 seconds.
for file: **http://www.cs.duke.edu/~ola/images/hiddenimage.jpg**

These results expire in **72 hours**. **Why?**

Share a success story!

TinEye is **free** to use for non-commercial purposes.

JPEG, 400x300, 17.3 KB

337 Results

Searched over **2.0907 billion** images in 1.081 seconds.
for file: **http://www.cs.duke.edu/~ola/images/bluedevil.jpg**

These results expire in **72 hours**. **Why?**

Share a success story!

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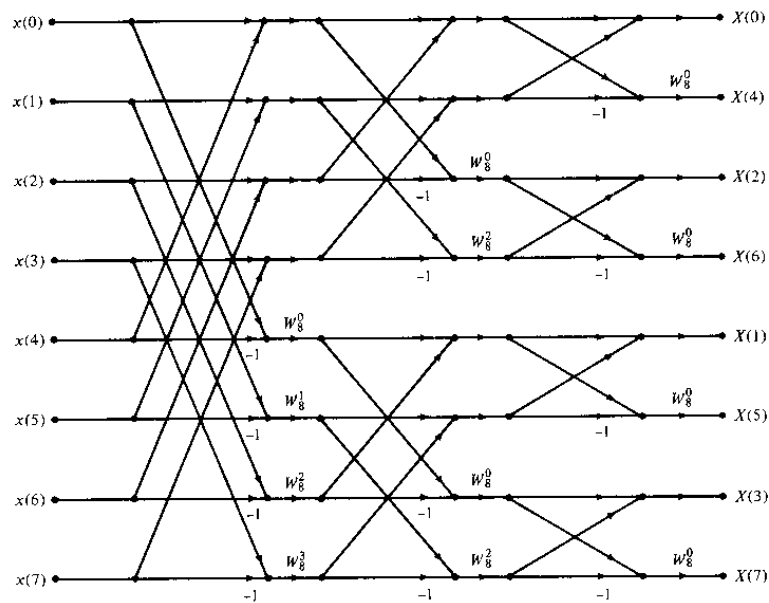JPEG, 400x300, 16.9 KB

Code to extract hidden image

```python
def extract_image(im):
  data = im.getdata()
  pic = Image.new(im.mode,im.size)

  ndata = [(r%4*64, g%4*64, b%4*64)
            for (r,g,b) in data]

  pic.putdata(ndata)
  return pic
```
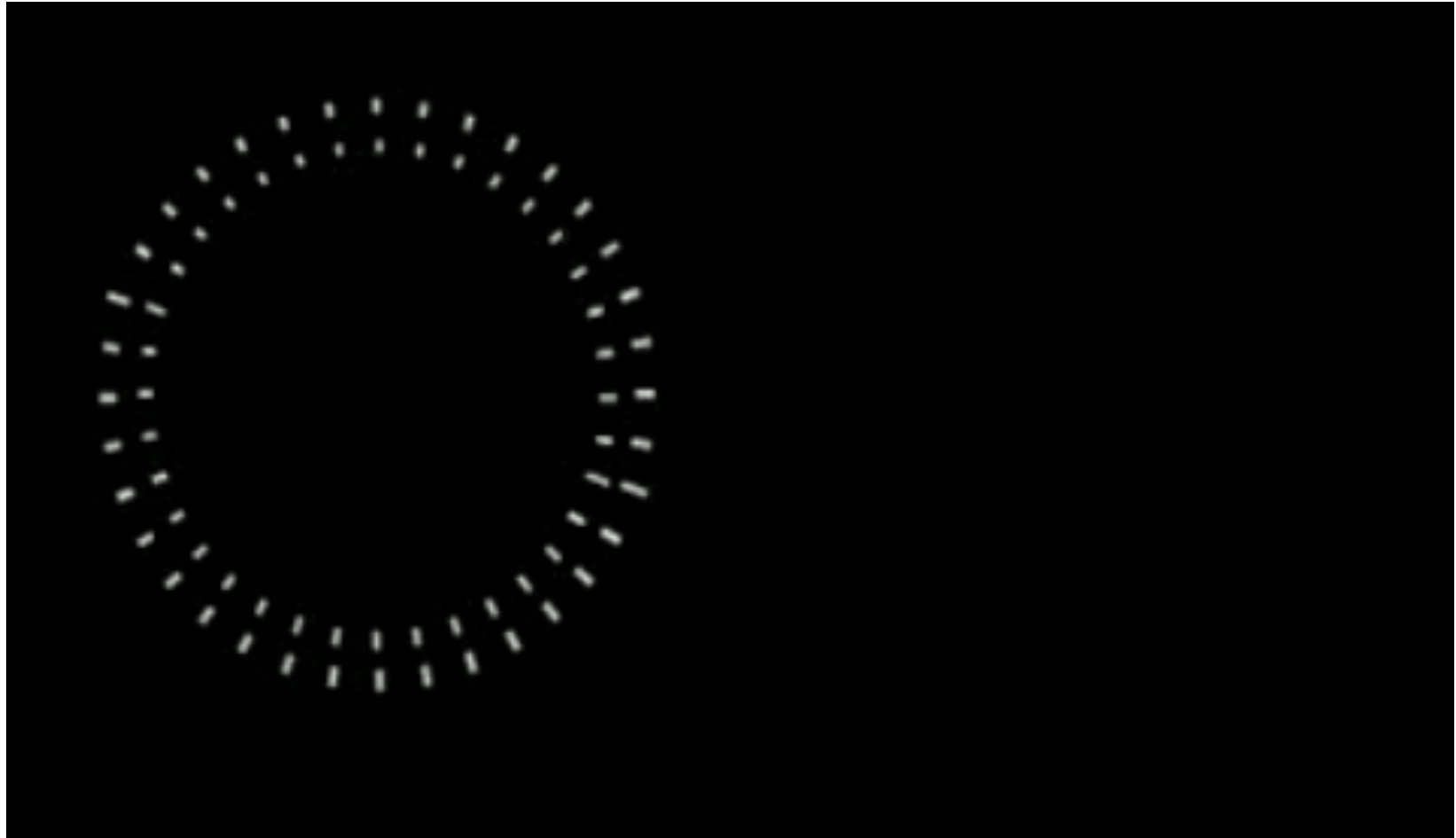
What's common to problems?

- **How is this similar to other examples?**
  - ➤ **Search for "big things" using "small" fingerprint**
  - ➤ **Power of abstraction? Power of data and scale?**

Database matching CSI style

What's wrong with this picture?

It's not about content, it's mostly about pedagogy

Toward expanding diversity and broadening participation

Purported Advantages of PBL

Cumulative learning to achieve growing familiarity through a sequence of learning experiences that are relevant to the student's goals, experiences that become progressively less straightforward but more complex, as well as less non-threatening but progressively more challenging.

Project-based, problem-centric, likely not PBL

Purported Advantages of PBL

Learning for understanding, rather than for recall of isolated facts, through appropriate opportunities to reflect on their educational experiences, and through frequent feedback, linked with opportunities to practice the application of what has been learned.

From Computational Thinking to two courses arguably related

One local, one national

How does indexing the web work?

➢ **Where is data stored, how is it ranked, how has this changed the way you work, live, play?**

Stories …, what do we teach?

- **Audience**
- **Content**
- **Expectations**
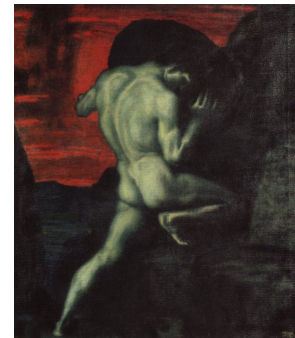- **Work ethic**
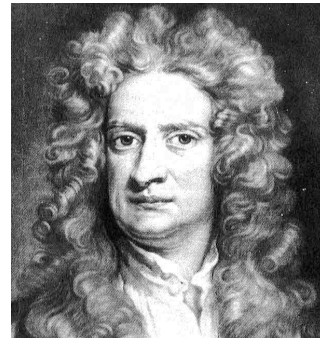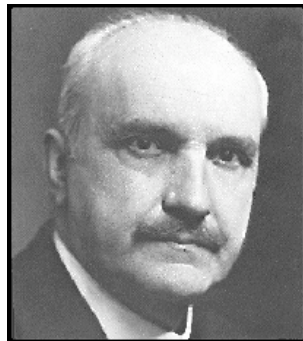
Where do we look for ideas?

- **Newton**
  - ➢ "If I have seen farther than others …"

- **Parnas**
  - ➢ "the wheel is reinvented so often because …"

- **Santayana**
  - ➢ "Those who cannot remember the past…"
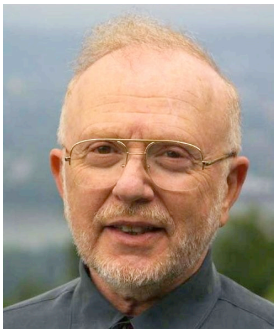
Changing Minds, Andy diSessa

- **Outside of schools, a computational literacy will allow civilization to think and do things that will be new to us in the same way that the modern literate society would be almost incomprehensible to preliterate cultures.**

- **..by computational literacy I do not mean a casual familiarity with a machine that computes…**

WWNPD?

- **Confronted with a student who is bored with the real world, I don't think we can get away so easily by making available a virtual-reality physics lab.**

- **..the classroom is intended to tame the ego, to connect the individual with others, to demonstrate the value and necessity of group cohesion [unlike, e.g., some uses of technology]**

- **What should students who aren't programming learn about computer science?**

- **What should students will be be our next ＿＿＿ learn?**

IP^2

There's no place like 127.0.0.1
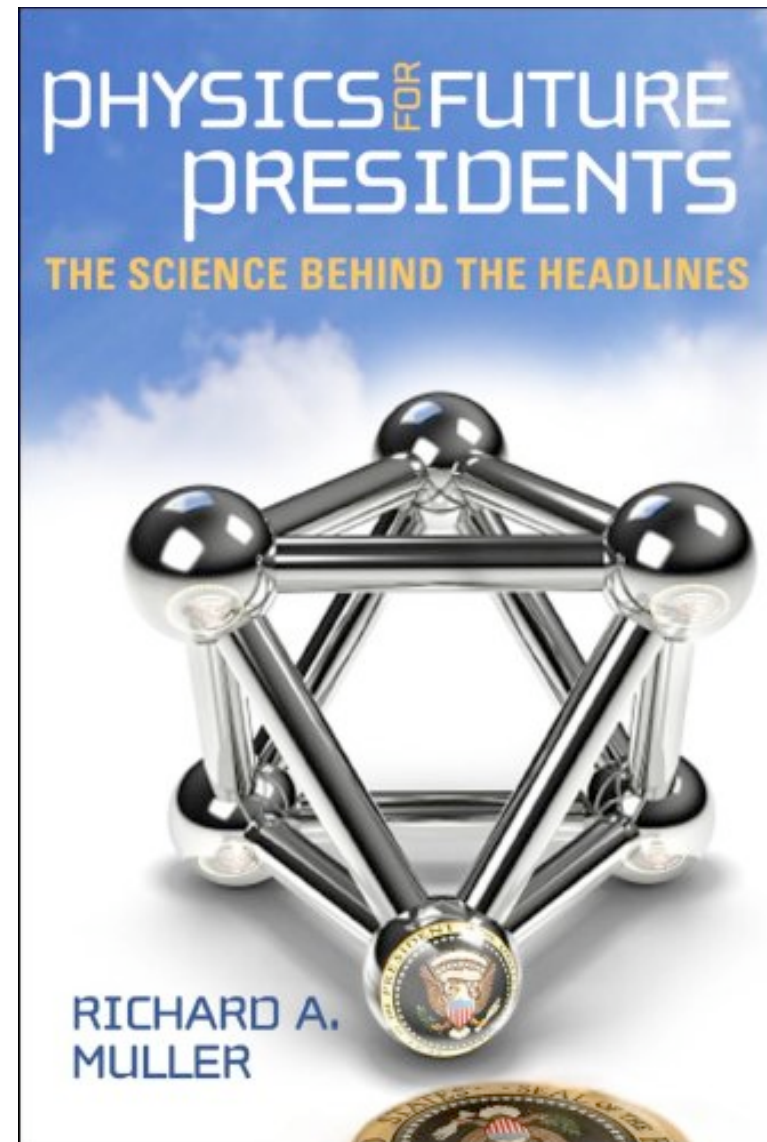
INTELLECTUAL PROPERTY
INTERNET PROTOCOL

High level view of the course

- **Internet origins**
- **Internet governance**
- **IETF, ICANN, DNS**
- **Blogs, Ads, Politics**
- **E-voting**
- **Copyright, patents**
- **Open Source**
- **Anonymity, ethics**

- **p2p, DRM, DMCA**
- **Privacy**
- **Spam**
- **Phishing**
- **Cybercrime/war**
- **Hacktivism**
- **Internet Censorship**
- **Ads/Auctions**

http://www.youtube.com/watch?v=ZY72fX-ESpk
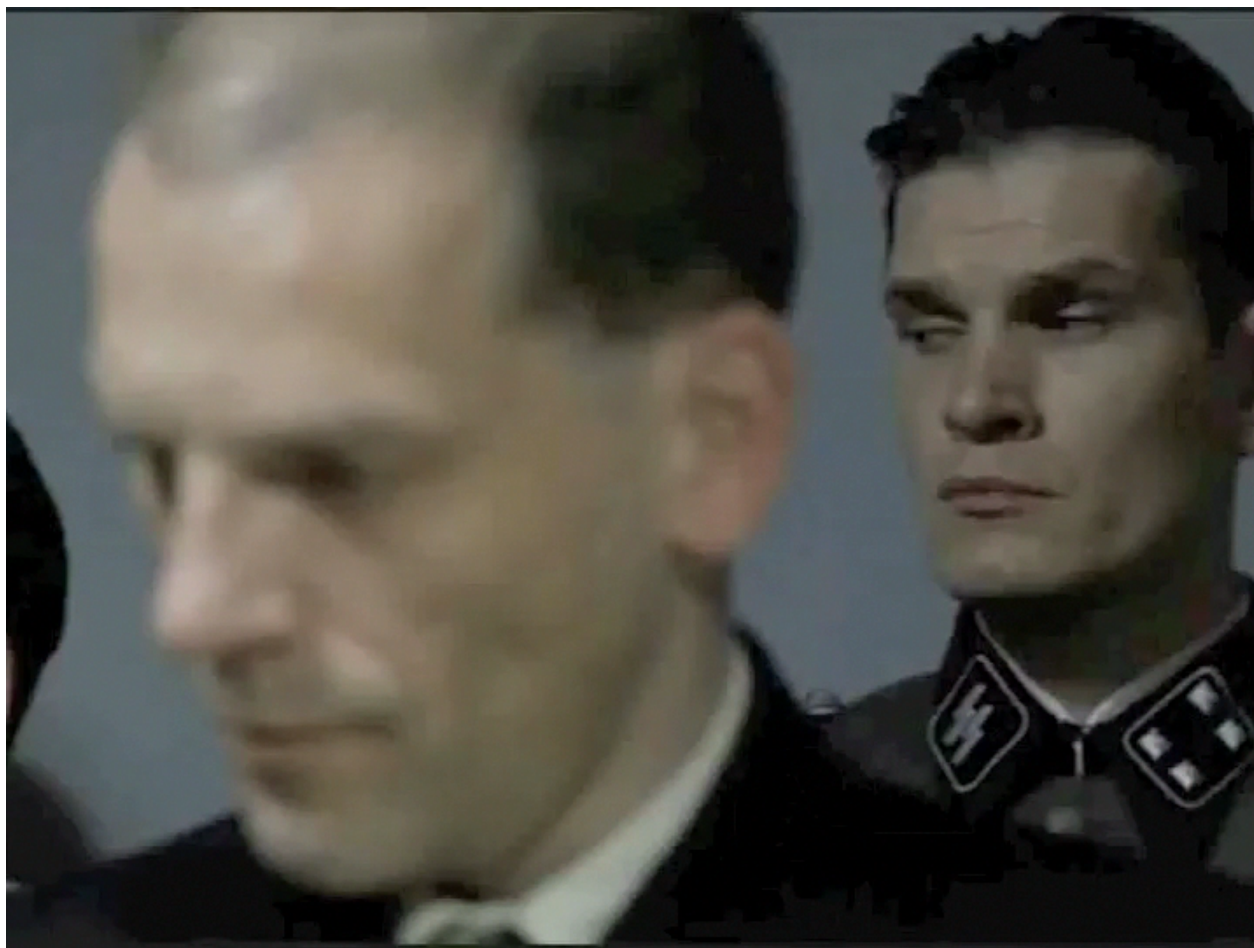
CS PRINCIPLES

What, who, why, where, when

What is CS Principles?

- **A first course in computer science**
  - ➢ **So what are the prerequisites?**

- **Designed to be an AP course**
  - ➢ **National leverage**
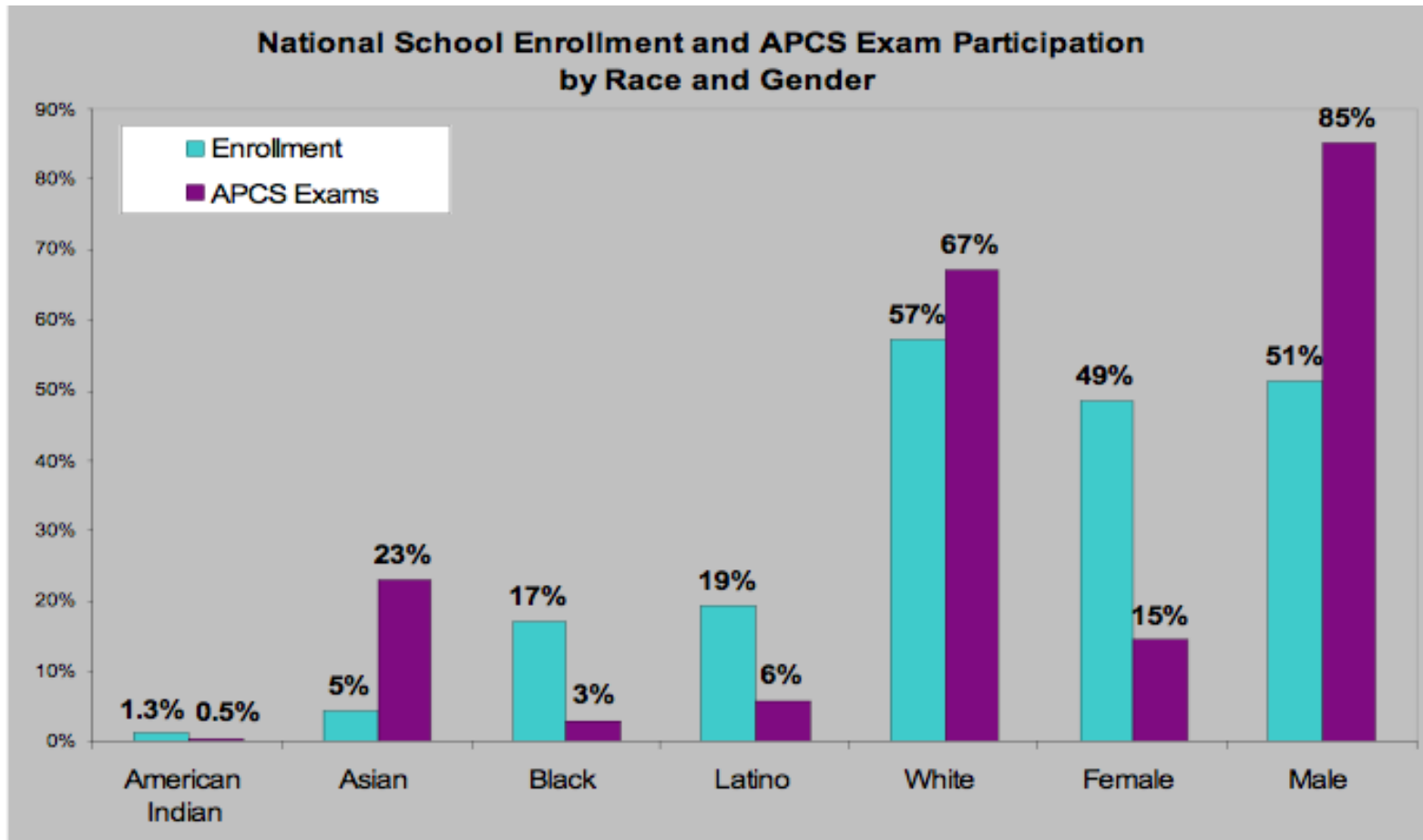
- **Collaboratively developed**
  - ➢ **NSF, College Board, (ACM, CSTA, Google)**

Alternative to CS1, Not replacement!

Who?

61

APCS exam demographics

National School Enrollment and APCS Exam Participation by Race and Gender

Slide: CSTA, Data: College Board

How to design a *new* AP course

- **Convene a group/commission with an advisory board**
  - ➢ **Use evidence-centered design**
  - ➢ **Claim: student has specific knowledge or skill**
  - ➢ **Evidence: behavior or performance that skill/ knowledge has been achieved**

- **Develop Seven Big Ideas, Six Computational Thinking Practices**
  - ➢ **Test, Redesign, Repeat**

The seven big ideas

1   Computing is a *creative* activity

2   *Abstraction* reduces information and detail to focus on relevant concepts

3   *Data* and information facilitate the creation of knowledge

4   *Algorithms* are used to develop and express solutions to computational problems

5   *Programming* enables problem solving, human expression, and creation of knowledge

6   The *Internet* pervades modern computing

7   Computing has global *impacts*

Previous and related work

- ## On the one hand, this is new
  - ➢ **Related to significant body of previous work**

- ## Attestation process validated project; the right schools indicated
  - ➢ **Good idea**
  - ➢ **Credit given**
  - ➢ **Placement given**
  - ➢ **Teach the course**

Toward another first course

- **Harvard CS50, CS1**

- **Stanford CS 106A, CS 105**

- **Princeton COS 126, 116/109**

- **Berkeley CS61A, CS10**

- **Texas, CS 305J, CS 302**

- **Wisconsin, CS 302, CS 250/202**

- **Colorado CSCI 1300, 1220/1000**

Toward another first course

- **Tufts, Comp 11, Comp 9,7**

- **Clemson CPSC 101, CPSC 120**

- **USC, CS 101L, Nothing**

- **Virginia Tech, CS 1054, CS 1614**

- **U. Kansas, EECS 168, EECS 128**

- **Brown, CSCI 150, CSCI 20**

- **U. Mass, CMPSCI 121, CMPSCI 120**

Timeline

- **2009-2010**
  - ➢ **Drafted curriculum framework: big ideas**

- **2010-2011**
  - ➢ **Pilot in five colleges, Attestation, College Survey**

- **2011-2012**
  - ➢ **Pilot in 10 colleges/high schools partnered, testing**

Next steps

- **Develop an assessment for national course**
  - ➢ **Portfolio based exam**
  - ➢ **Delivered electronically**

- **Assess the pilot courses**
  - ➢ **What were the learning outcomes**
  - ➢ **Did participation broaden**
  - ➢ **Was curriculum delivered**

Deliver exam in 2015-16 as part of CS10K

Optimism is Essential