Slide 1

Algorithmic Education

Integrating Algorithmic Thinking into Education

The *other* way
Computer Science
Is changing Education

CUHK/CSAIL Workshop

25 March 2015

Hong Kong

Steve Ward

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Slide 2

First, learn the Basics: **Traditional Education**

- **Learned simultaneously**
- **Reinforce each other**
  - Language, Math, Cultural, Science skills each contribute vocabulary, subject matter to others
- **Rich interconnections**

Then Specialize!

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Slide 3

Algorithms as a basic conceptual tool

Like language/math/…,
algorithms **provide**

- New conceptual models for other basic skills
- New vocabulary for questions, answers
- New tools for every domain

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Slide 4

Algorithmic Education is not just…

Massive online deployment
- MOOCS are a parallel revolution …

Use of computer tools
- Languages, Simulation environments, Visualizations, Playpens, web resources ---

Pushing coding skills
- Coding.org, CodeDay.org,
- Getting coding skills into secondary education!

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Slide 5

... it's a new model for understanding!

Algorithmic insights/skills — I can PROGRAM it!

Interaction — I can teach it!

Language, Math

Modes of understanding

I can predict its behavior!

I can answer questions about it!

I can explain it!

I can describe it!

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Slide 6
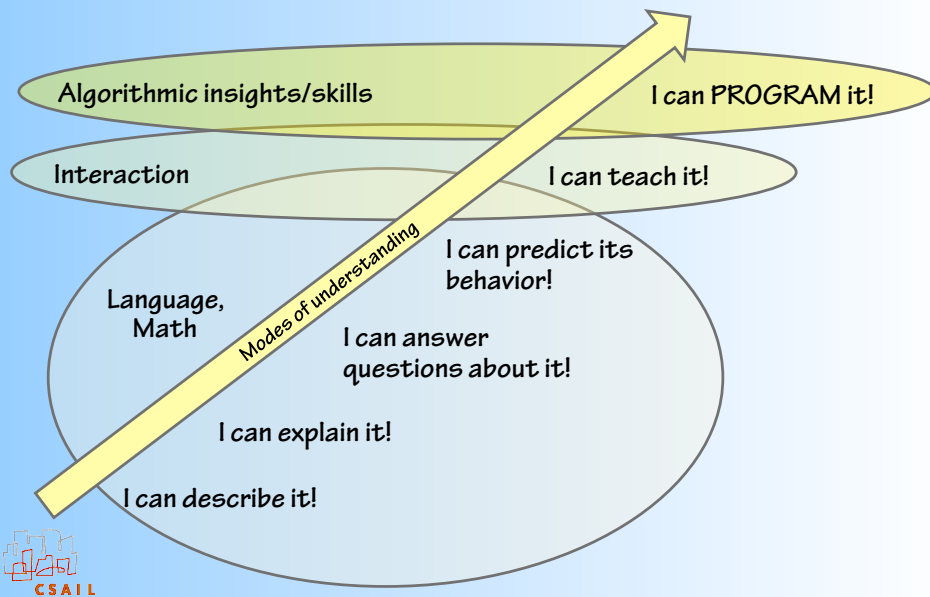
"Computational Thinking"

- Scattered early interest ...

  Seymour Papert (constructionism, LOGO):

  - 1997 "Computational Thinking" citation

  - Related mentions earlier, e.g. 1980:
    "The factor that will influence the development of children is the diffusion into their culture of computational concepts."
    http://www.papert.org/articles/RedefiningChildhood.html

2006: Jeannette Wing CACM article

Viewpoint | Jeannette M. Wing

Computational Thinking
It represents a universally applicable attitude and skill set everyone, not just computer scientists, would be eager to learn and use.

http://www.cs.cmu.edu-afs-cs-usr-wing-www-publications-Wing06.pdf

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E X P L O S I O N   in interest/activities/projects!

Slide 7

"Computational Thinking" Explosion

COMPUTER SCIENCE
Unplugged
An enrichment and extension programme for primary-aged children
Tim Bell, Ian H. Witten and Mike Fellows

Computational Thinking Toolkit

ISTE's Computational Thinking Toolkit is a complete collection of all of our CT resources. From presentations and handouts to surveys and graphic animations, you'll find everything you need to learn more about or to advocate for CT.

The Endowment for the Study of Computational Thinking
Russ Abbott

CS4FN
Computer Science For Fun

A magazine where the digital world meets the real world.

What is Computational Thinking?
One of the exciting things about learning Compute...

REPORT OF A WORKSHOP ON THE SCOPE AND NATURE OF COMPUTATIONAL THINKING

BANG!

Edited by Achim Menges and Sean Ahlquist
ROBERT KOWALSKI

LOOK INSIDE

COMPUTATIONAL THINKING

CT Presentation Tutorial
Carolyn Sykora, Senior Project Manager, ISTE

Google
Exploring Computational Thinking
Find related K-12 curriculum on the web   Search
Home
What is CT?
Getting Started with CT
Lessons and Examples
What is CT?
Computational thinking (CT) involves a set of problem-solving skills and techniques that software engineers use to write programs that underlie the computer applications you use such as search, email, and maps. However, computational thinking is...

Computational Thinking
Computer Science 6604
Fall, 2013

[Home] [Calendar] [Syllabus] [Papers] [Resources] [Policies]

Center for Computational Thinking
Carnegie M

Computational Thinking in K–12: A Review of the State of the Field
Shuchi Grover and Roy Pea[a]

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Slide 8

Invasion of Computational Thinking

ROLESIA
A MACROECONOMIC SIMULATION
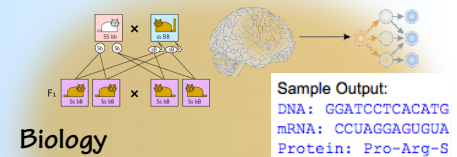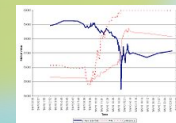
Economics
- Simulation. Game theory.
- Pricing models. Programmed trading. Flash crash. Bitcoin.

$$C = SN(d_1) - N(d_2)Ke^{-rt}$$

Biology
- Genome as code; interpretation.
- Natural selection; evolution
- Models of intelligence

Sample Output:
DNA: GGATCCTCACATG
mRNA: CCUAGGAGUGUA
Protein: Pro-Arg-S

Arts
- Abstraction: Science of Art
- Profiling models: programming "taste"?

PANDORA | ONE
NETFLIX

Epagogix
experience • knowledge • prediction

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Slide 9 — Great Thinkers using CT…

$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$$
$$\nabla \cdot \mathbf{B} = 0$$
$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$
$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$
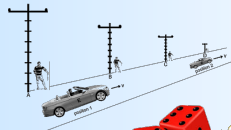
James C. Maxwell's Code Review

Maxwell's correction to Ampere's Law:

Reverse-engineering the universe!

- Changing magnetic field => electric field;
- Why not the other way around?
  - Cycle: Changing E => changing B => changing E => …
  - Self-perpetuating "electromagnetic wave"?
  - Propagates at … speed of light??? *Eureka!*

```
// exact speed of light,
// m/sec:
const C=299792458;
```

Einstein's insights …

- How can C be a constant?
  - depend on frame of reference?
  - No! Would require frame-dependent code!
- Does God play dice with the universe?
  - Translation:
    - Does Universe run on randomized algorithm?

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Slide 10 — …and great thinkers *needing* CT

Mind-Body Problem …

- Philosophers have wrestled for millennia with relation between physical & mental phenomena … Plato, Descartes, Kant, …
- Mind – Body dualism?

  Missing: Information. Algorithm. Interpretation. State.

Rene Descartes   Cartesian Dualism

… but to us computer geeks

- Computers provide rich models:
  - Hardware vs Software
  - Information stored as transient state
 - Processes, state, identity, … have crisp meanings
- *So what's the problem???*

No longer an **"Interesting Problem"???**

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Slide 11 — CT in University Education

1980s Adler/Sussman EE via CS

- Many use simulators to teach EE …
  - *Code as a hardware replacement*
- Added wrinkle: Teach students *how to build the simulator!*
  - *Code as a conceptual model*
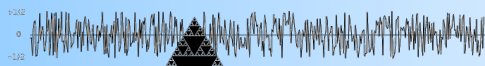 - *If you can build SPICE, you really understand electronics!*
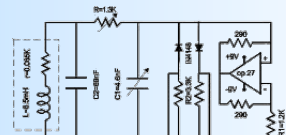
```
Class Resistor (LTIDevice):

    def __init__(*args, **kwargs):
        super(Resistor, self).__in
```

Princeton COS 126

- Programming, via STEM examples
- Digital "wet lab" replacements:
  - N-body simulation
  - Fractal art
  - Simulation of guitar string
  - Random text using Markov model
  - Estimating Avogadro's number, from image data

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Slide 12 — CT in K-12

Programming

- Kids languages, eg Scratch (ages 8-18)
- Game design environments
- "Hour of code", etc

```
when    clicked
play sound  meow
repeat 12
move 10 steps
turn  30 degrees
```

AgentCubes Creativity3D

SCRATCH

MIT App Inventor

COMPUTER SCIENCE Unplugged
An enrichment and extension programme for primary-aged children
Created by Tim Bell, Ian H. Witten and Mike Fellows

CT Models & resources

- Computer Science Unplugged: CT without computers!
- Resources for K-12 teachers

WORLD of GOO

Games

- Build intuition, CT skills
- Creative playpen!

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Slide 13

Cosmic View

We've all seen simulation games…

- *"Sims"*: primitive models of humans
  - Simulated hunger, love, lust, anger
  - Simple, but evolved only for a few decades
- Imagine **more highly evolved sims** …
  - Sims reverse engineer the game code?
  - Speculate about their own implementation?
  - Hack their programmed universe?
- *Reflection* threshold: awareness of own code

?

*#@!

Primitive Sims

SimUnivers…

- *Our u…*
- *W…*
- *What's o…*
- *Infinite hierarchy of universes?*
- *Big Bang: time of last reboot?*
- *God: sysop in some higher universe?*
  - *15-year-old kid playing video game?*
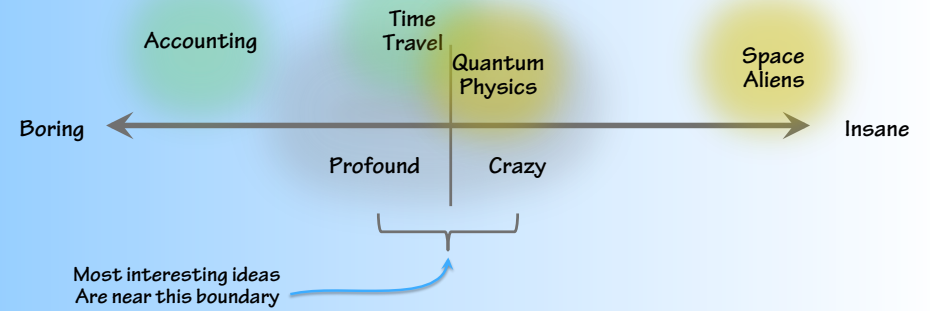 - *Prayers as bug reports, feature requests…*

> uptime
This universe has been running for 13.7B years.

This guy is CRAZY!

He thinks we're all SIMS???

Slide 14

That fuzzy boundary …

… between Profound & Crazy:

Accounting

Time Travel

Quantum Physics

Space Aliens

Boring ⟵――――――――――――⟶ Insane
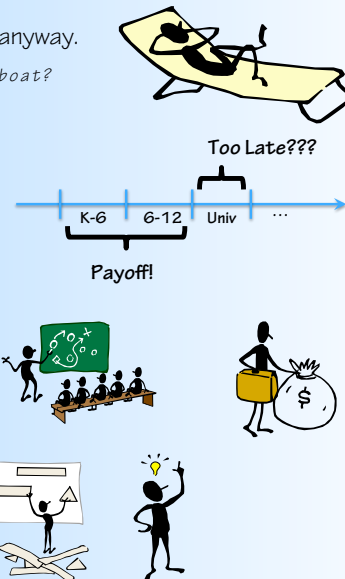
Profound | Crazy

Most interesting ideas
Are near this boundary

Creative Thinking:
   exploring *both* sides of this boundary!
Algorithms – Computational Thinking –
   Essential tool for doing so!

Slide 15

So, what do *we* do???

- **Nothing.**
  - Computational Thinking is taking over anyway.
  - *The Leading Edge: Will **our** kids miss the boat?*

- **College courses using CS for xyz**
  - Spread the application of Computer Thinking to other disciplines…
  - *Teach CT to next **Teachers**!*
  - *Generational Time Constant*

- **Re-educate current HS teachers**
  - Circumvent **GTC** …
  - *Will they all go to Google?*

- **Develop tools, languages, ideas**
  - *"Fuel the fire"!*

Too Late???

K-6 | 6-12 | Univ | …

Payoff!

Slide 16

Computation in Education

UDACITY

Google

Teaching

Learning

edX

WIKIPEDIA

1001110101100011…

Thinking