# Informatics and General Education

Walter Gander

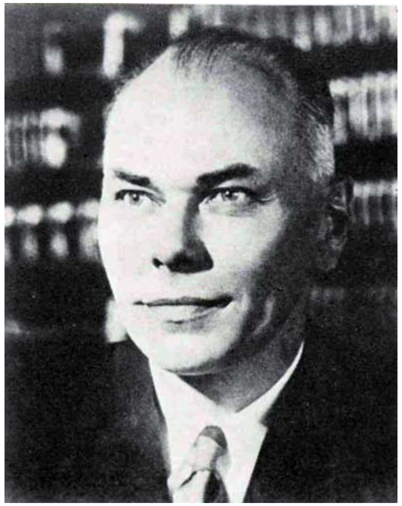
ETH Zurich and BU Hong Kong

ISSEP 2014
22–25 September 2014, Istanbul

Computers have been invented . . .

for computing!

# Two Computer Pioneers



Howard Aiken, physicist:
constructor of the HARVARD MARK I, 1944
system of differential equations with 4 functions,
no analytic solution,
$\Longrightarrow$ compute numerical approximation

Konrad Zuse, civil engineer:
constructor of the Z3 (first programmable computer using binary floating point numbers, 1941)
"large" ($n \approx 20$) linear systems of equations,
$\Longrightarrow$ compute solution

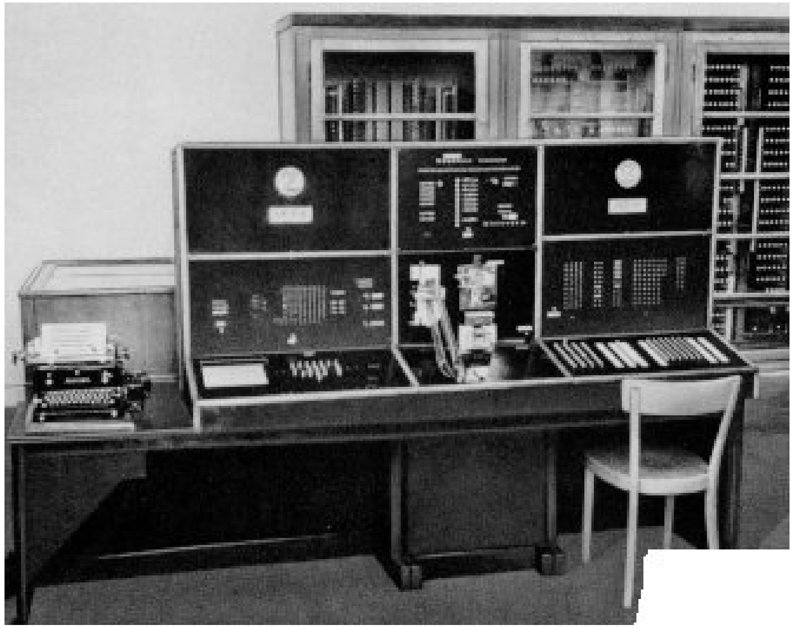
# Start of CS in Switzerland

Zuse's Z4 at ETH

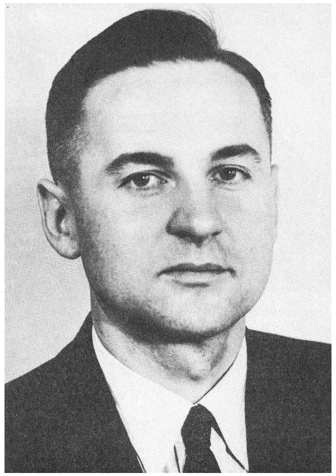
leased 1950-1955 by E. Stiefel

collaborators:

A. Speiser, H. Rutishauser (1955)

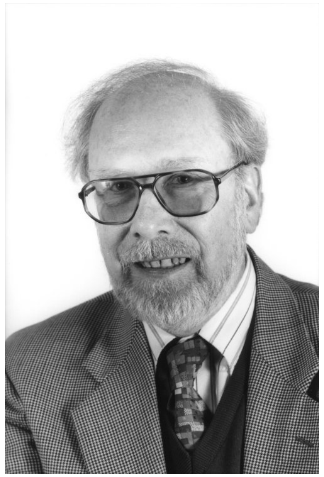


# Developer of Programming Languages



One of the fathers of ALGOL

Handbook Series Vol 1:
HEINZ RUTISHAUSER
*Description of* ALGOL 60, 1967



PASCAL: Report by NIKLAUS WIRTH and KATHLEEN JENSEN, 1975
MODULA: Programming in Modula-2
NIKLAUS WIRTH, 1982
OBERON: J. GUTKNECHT, N. WIRTH:
Project Oberon. The Design of an Operating System and Compiler, 1992

# CS Education in Switzerland

- In spite of impressive pioneering achievements no immediate influence on education
- University: Introduction of a CS-curriculum at ETH only 1981
- Schools: Slide rule slowly replaced by pocket computer
- Gymnasium:
  - 1984 planing for computer science in STEM-oriented tracks
  - 1986 Urs Hochstrasser renames Descriptive Geometry to Applied Mathematics

Urs Hochstrasser
Director
Swiss Federal Office
for Education and Science
1969–1989

# CS in Gymnasia 1986

- PC with almost no applications
  therefore main activity:
  - system installation
  - programming in BASIC or PASCAL
- produced some enthusiastic high-school students; now good computer scientists
- frustrated teachers:
  - frequent breakdowns and system changes
  - students nerds know more



# Development after 1995

- many applications available, no need to develop themselves
- computer cheaper, ubiquitous and easier to handle (e.g. Macintosh)
- the INTERNET is available
- strong movement: no need to learn programming anymore
- instead: learn to make good use of computer tools $\Longrightarrow$ ICT
- applications become more complex, teachers have to be trained
- Intel and Microsoft offer training for their products to whole countries


2000 Edition

# Today: We Live in a Digital World

**Communication:** e-mail, cell-phone, sms, social networks: facebook, twitter, LinkedIn . . .

**Writing:** text-processing, spreadsheets, presentation tools, desk-top publishing

**Reading:** Google eBooks, e-Reader: Kindle, iPad, Sony Reader, Digital Book Index provides links to more than 165,000 full-text digital books `http://www.digitalbookindex.com/about.htm`

**Music:** iTunes, e-music, MP3, napster

**Radio and Television:** digital, Internet, YouTube

**Photography:** software has replaced chemically processed films

**Search for Information:** libraries, archives available on-line, Wikipedia

**Total Surveillance:** Edward Snowdon . . .

**many more examples . . .**

## Dependency on "New Media"

- We have become intensive users of ICT
- Switzerland: 80% of age 12–19 possess a smart-phone
- Zurich drug prevention agency: withdrawal symptoms when doing without smart-phone for 3 days
- Too much new media causes "digital dementia":
  - South Korea study: young people cannot remember their phone number [a]
  - also observed by Manfred Spitzer, psychiatric hospital Ulm [b]
- $\Longrightarrow$ need media education in curricula

---

[a] http://www.telegraph.co.uk/news/worldnews/asia/southkorea/10138403/Surge-in-digital-dementia.html

[b] https://www.youtube.com/watch?v=FnDEF7Aw9HI

# Topics of Media Education in Saarland

http://www.saarland.de/3402.htm

- Gudelines for dealing with social networks
- Make children fit for the Future Internet
- Student Workshops: "Learning with data protection specialists"
- Media Consultants & Media Scouts in schools
- "Media education in school" (KMK) [a]
- Using music and video in the classroom
- Photo copying and scanning in schools
- ECDL [b] including Google services (Google Drive, Google+, Google Calendar, Google Play, Moodle)

---

[a] Kultusministerkonferenz=conference of the Education Ministers of Germany

[b] European Computer Driving Licence http://www.ecdl.com/:

# What is General Education?

- German "Allgemeinbildung" (literal: general education) means all-round education, general knowledge, liberal education
- It is the basic knowledge humans need to understand our world
- At the time of Leonardo da Vinci (1452-1519):
  obtain general education by studying all available books!
- Today: knowledge explosion, must choose
- Swiss Gymnasium:
  *High school graduates know and are familiar in their natural, technical, social and cultural environment, and this in relation to the present and the past, at national and international level.*

## Contents of General Education

- Fundamentals, long lasting basic knowledge
  not ephemeral knowledge, not vocational training
- Traditional unquestioned fundamental subjects are e.g.
  mathematics, chemistry, physics, biology.
- no high-tech without mathematics
  no engineering without physics and chemistry
  no medicine without biology

## Contents of General Education

- Fundamentals, long lasting basic knowledge
  not ephemeral knowledge, not vocational training
- Traditional unquestioned fundamental subjects are e.g.
  mathematics, chemistry, physics, biology.
- no high-tech without mathematics
  no engineering without physics and chemistry
  no medicine without biology
- However, today
  nothing works without computer science!

## Contents of General Education

- Fundamentals, long lasting basic knowledge
  not ephemeral knowledge, not vocational training
- Traditional unquestioned fundamental subjects are e.g.
  mathematics, chemistry, physics, biology.
- no high-tech without mathematics
  no engineering without physics and chemistry
  no medicine without biology
- However, today
  nothing works without computer science!

$\Longrightarrow$ computer science belongs to the fundamental technical subjects

# Impact of Computer Science: Computational X

Computational Material Science

Computational Biomechanics

Computational Finance

Computational Physics

Computational Chemistry

Computational Biology

Computational Linguistics

Computational Fluid dynamics

Computational Geometry

Computational Neuroscience

Computational Legal Studies

Computational . . .

all sciences benefit from computer science

# Traditional Approach in Scientific Research

**Experimentation** $\longleftrightarrow$ **Theory**

measure, observe — develop models

# Computational Science as “third pillar of science”

**Experimentation**
measure, observe

**Theory**
develop models

**Computational Science**
simulations with computers

# What is Computer Science?
# What should be taught in schools?

- The "Informatics Europe&ACM Europe Working Group" defined in their report (April 2013): [a]

  Computer Science in Schools = Digital Literacy + Informatics

- Digital Literacy (often called ICT) is about the use of computers
- Informatics covers the science behind information technology
- Both parts should be taught compulsory in European schools for all students from first grade on.

---

[a] Informatics education: Europe cannot afford to miss the boat. Report of the joint *Informatics Europe & ACM Europe Working Group on Informatics Education*, April 2013 `http://www.informatics-europe.org/images/documents/informatics-education-europe-report.pdf`

.


# MICHAEL GOVE

## Secretary of State for Education in UK

Speech of January 2012 [a]

$\Longrightarrow$ Turning point

- *the UK had been let down by an ICT curriculum that neglects the rigorous computer science and programming skills which high-tech industries need.*
- *In short, just at the time when technology is bursting with potential, teachers, professionals, employers, universities, parents and pupils are all telling us the same thing: ICT in schools is a mess.*

[a] https://www.gov.uk/government/speeches/michael-gove-speech-at-the-bett-show-2012

# Michael Gove (cont.)

- *The new Computer Science courses will reflect what you all know: that Computer Science is a rigorous, fascinating and intellectually challenging subject*
- Initiatives like the Raspberry Pi scheme [a] will give children the opportunity to learn the fundamentals of programming with their own credit card sized, single-board computers.
  It could bring the same excitement as the BBC Micro did in the 1980s[b]
- Imagine the dramatic change which could be possible in just a few years, once we remove the roadblock of the existing ICT curriculum. Instead of children bored out of their minds being taught how to use Word and Excel by bored teachers, we could have 11 year-olds able to write simple 2D computer animations using an MIT tool called Scratch. (`http://scratch.mit.edu/`)

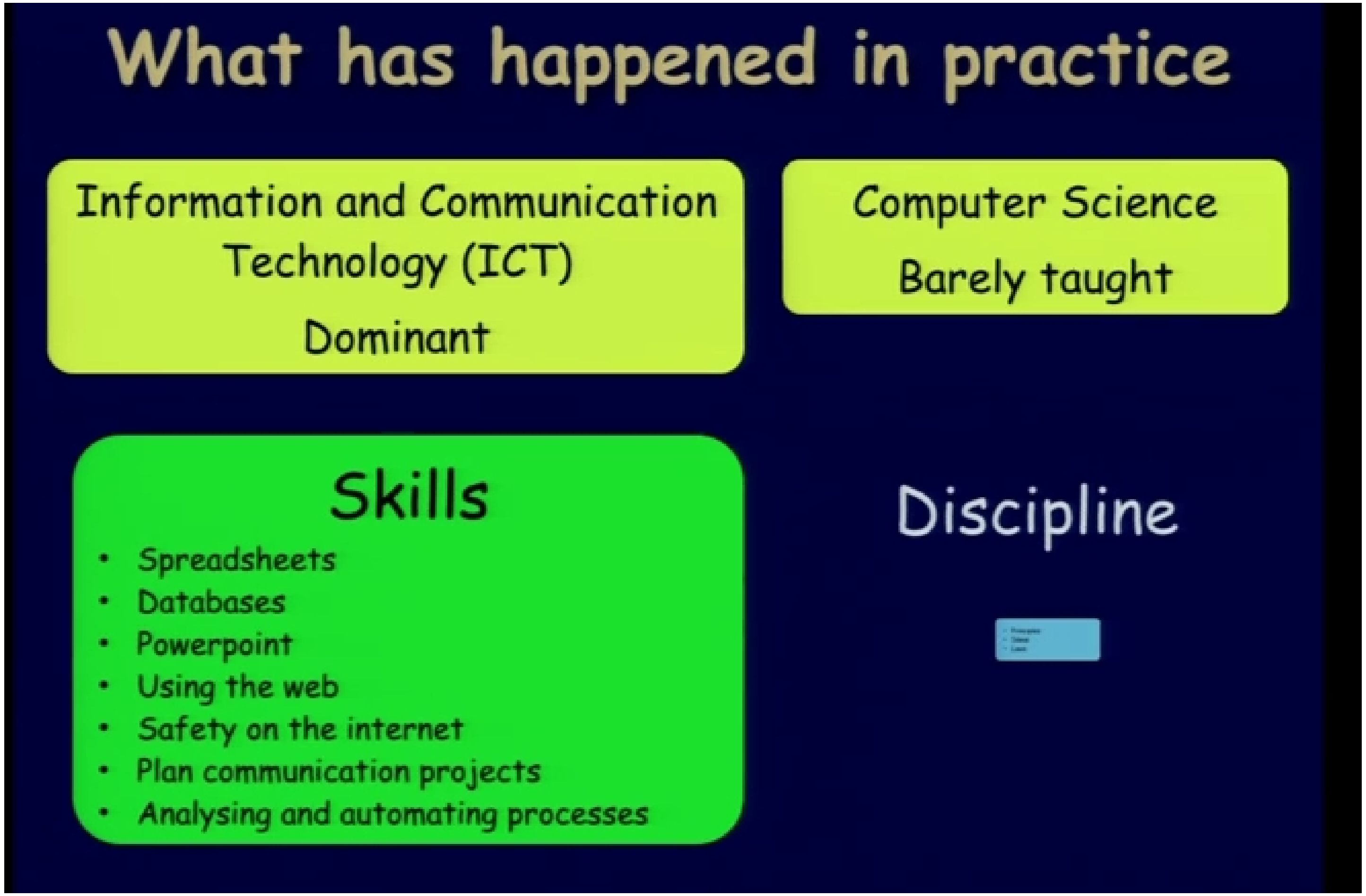
[a] ICT↔CS:David Braban
[b] also: Commodore 64, Amiga . . .

# Too much Emphasis on ICT

SIMON PEYTON JONES: Teaching creative computer science

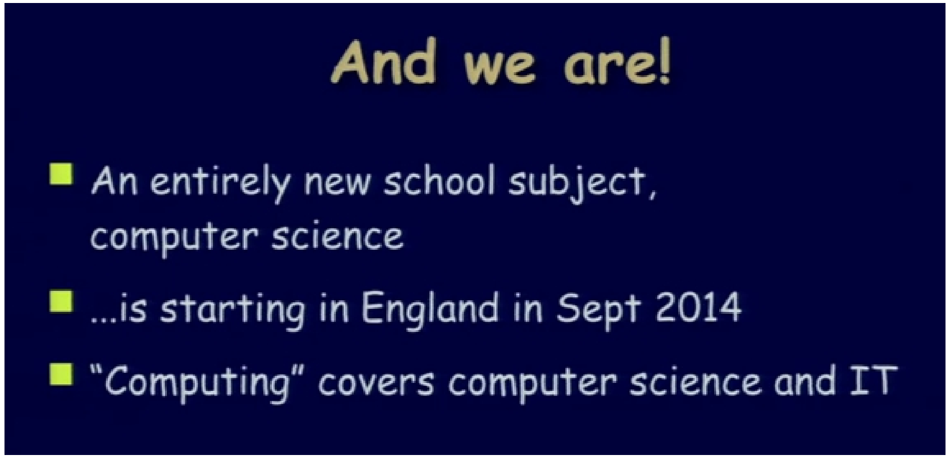
https://www.youtube.com/watch?v=Ia55clAtdMs (TED talk, May 6, 2014)

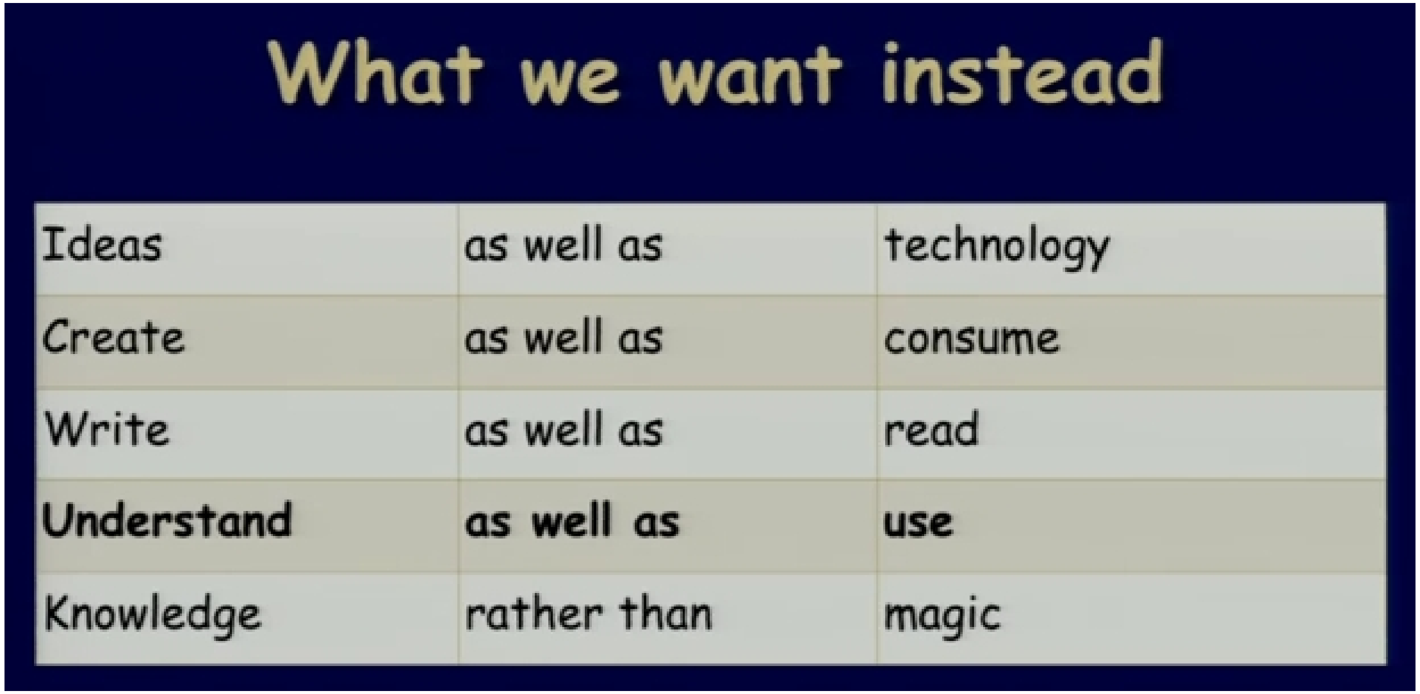
- Simon distinguishes between skills=ICT and discipline=informatics



# Reform in UK, September 2014 (talk Simon Peyton Jones)

.




| | | |
|---|---|---|
| Ideas | as well as | technology |
| Create | as well as | consume |
| Write | as well as | read |
| **Understand** | **as well as** | **use** |
| Knowledge | rather than | magic |

## George Forsythe wrote 1963:

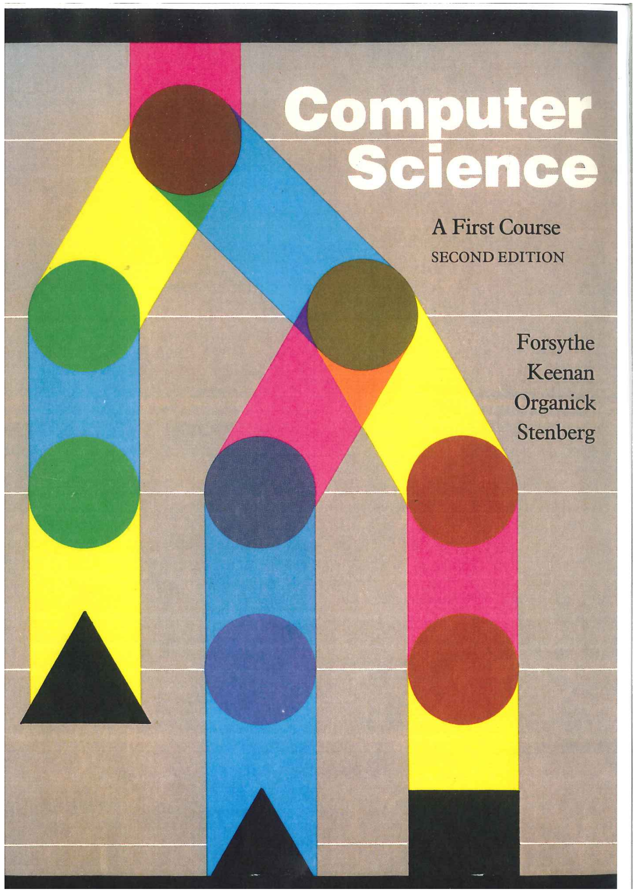
Founder of
CS-Dept. Stanford
A Father of
Silicon Valley

*Machine-held strings of binary digits can simulate a great many kinds of things, of which numbers are just one kind. For example, they can simulate automobiles on a freeway, chess pieces, electrons in a box, musical notes, Russian words, patterns on a paper, human cells, colors, electrical circuits, and so on. To think of a computer as made up essentially of numbers is simply a carryover from the successful use of mathematical analysis in studying models . . . Enough is known already of the diverse applications of computing for us to recognize the birth of a coherent body of technique, which I call computer science.* [a]

[a] Educational implications of the computer revolution. Applications of Digital Computers, W. F. Freiberger and William Prager (eds.), Ginn, Boston, 1963, pp. 166-178.

# A Textbook of 1969/1975!

more than 40 years ago!!




Contents

## Programming – a Fundamental of Informatics!

GEORGE FORSYTHE 1959: *The automatic computer really forces that precision of thinking which is alleged to be a product of any study of mathematics.* [a]

GEORGE FORSYTHE 1966: *The major thing which distinguishes computer science from other disciplines is its emphasis on algorithms.*

*There are few problems for which a good algorithm of probable permanent value is known... Small details are of the greatest importance... The development of excellent algorithms requires a long time, from discovery of a basic idea to the perfection of the method... A useful algorithm is a substantial contribution to knowledge. Its publication constitutes an important piece of scholarship.* [b]

[a] The role of numerical analysis in an undergraduate program. Amer. Math. Monthly 66 (1959), 651-662.

[b] Algorithms for scientific computation. CACM 9 (Apr. 1966), 255-256.

## Teaching a Machine

*If you want to learn something, teach it. You are successful if people understand. However, they may say they understand even if they don't.*

*The ultimate test if you are doing well is to teach it to a machine!*

(not literally)

DON KNUTH
Swiss Olympiad in Informatics
ETH Jan 14, 2012

*Programming a machine is part of our culture*

Berufsbildungskonferenz
Nov 9, 2012, Bern

MAURO DELL'AMBROGIO
Secretary of State
Education and Research
Switzerland
(the Michael Gove of Switzerland)

## President Obama: [a]

### High Schools Should Offer Programming and Graphic Design Courses [b]

> *Given how pervasive computers and the Internet is now and how integral it is in our economy and how fascinated kids are with it, I want to make sure that they know how to actually produce stuff using computers and not simply consume stuff*
>
> ...
>
> *We're going to start setting those programs in our high schools, not waiting to go to community college.*

[a] Fireside Hangout on Google+, Mountain View, Feb 2013

[b] `http://tinyurl.com/pgf2cx2`

# Everybody Should Learn to Program `http://www.code.org/`

## Leaders and trendsetters agree more students should learn to code

**President Bill Clinton**
"At a time when people are saying "I want a good job - I got out of college and I couldnt find one," every single year in America there is a standing demand for 120,000 people who are training in computer science."

**Marco Rubio**
Senator, Florida
"Computer programmers are in great demand by American businesses, across the tech sector, banking, entertainment, you name it. These are some of the highest-paying jobs, but there are not enough graduates to fill these opportunities."

**Bill Gates**
Chairman, Microsoft
"Learning to write programs stretches your mind, and helps you think better, creates a way of thinking about things that I think is helpful in all domains."

**Mark Zuckerberg**
Founder, Facebook
"Our policy at Facebook is literally to hire as many talented engineers as we can find. There just aren't enough people who are trained and have these skills today."

**will.i.am**
Musician/The Black Eyed Peas and Entrepreneur
"Here we are, 2013, we ALL depend on technology to communicate, to bank, and none of us know how to read and write code. It's important for these kids, right now, starting at 8 years old, to read and write code."

**Sheryl Sandberg**
Chief Operating Officer, Facebook
"An understanding of computer science is becoming increasingly essential in today's world. Our national competitiveness depends upon our ability to educate our children – and that includes our girls – in this critical field."

**Vice President Al Gore**
"Our civilization is experiencing unprecedented changes across many realms, largely due to the rapid advancement of information technology. The ability to code and understand the power of computing is crucial to success in today's hyper-connected world."

**Chris Bosh**
NBA All-star, Miami Heat
"Coding is very important when you think about the future, where everything is going. With more phones and tablets and computers being made, and more people having access to every thing and information being shared, I think it's very important to be able to learn the language of coding and programming."

+ 756'432 others . . .

A pledge for Programming by Celebrities   Short version

# World-wide Movement: Programming in Schools is in!

The New York Times | http://nyti.ms/1jsvs4V

U.S. | NYT NOW

## Reading, Writing, Arithmetic, and Lately, Coding

By MATT RICHTEL MAY 10, 2014

MILL VALLEY, Calif. — Seven-year-old Jordan Lisle, a second grader, joined his family at a packed after-hours school event last month aimed at inspiring a new interest: computer programming.

“I’m a little afraid he’s falling behind,” his mother, Wendy Lisle, said, explaining why they had signed up for the class at Strawberry Point Elementary School.

# European Commission, July 2014 [a]

.

- The European Commission (EC) is urging people to learn coding this Summer, warning that a lack of basic coding skills could result in Europe facing a shortage of up to 900,000 ICT professionals by 2020.
- Coding is the literacy of today and key to enable the digital revolution, according to European Commission vice president for Digital Agenda, Neelie Kroes, and commissioner for education, culture, multilingualism and youth, Androulla Vassiliou.
- Programming is everywhere and fundamental to the understanding of a hyper-connected world, the EC has said.
- EU Code Week, taking place across Europe 11-17 October 2014 [b]

---

[a] Article in ComputerWeekly by Archana Venkatraman, 30 July 2014, http://tinyurl.com/mhq3tub

[b] EU Code Week

# Why is Programming IMPORTANT for General Education?

- Not for increasing the IT-workforce ! (Though also badly needed)

  Teaching mathematics, physics, chemistry, biology is also not for increasing workforce but for understanding our world.

- Programming is an activity which is
  - creative and
  - constructive work like an engineer!

  and teaches
  - precise working and
  - computational thinking

## Computational Thinking: Topic of General Education.

- Definition by Jan Cuny, Larry Snyder, and Jeannette M. Wing [a]

  *Computational Thinking is the thought processes involved in formulating problems and their solutions so that the solutions are represented in a form that can be effectively carried out by an information-processing agent.*

- Singapore Management University! [b]

  *Computational thinking is about problem solving that uses fundamental concepts in computer science, such as abstraction, decomposition, recursion, heuristic reasoning, just to name a few. It can be used to algorithmically solve complex problems of scale, and is often used to realize large improvements in efficiency.*

---

[a] Carnegie Mellon University, USA, http://www.cs.cmu.edu/~CompThink/

[b] http://sis.smu.edu.sg/computationalthinking

# Computational Thinking is for Everybody

- Jeannette M. Wing wrote in CACM [a]

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

- Computational thinking: a methodology for anyone for solving problems with computers. It involves the following steps
  - Analyze a task or problem, model and formalize it.
  - Search for a way to solve it, find or design an algorithm.
  - Program.
  - Run the program: let the computer work, maybe correct, modify the program,
  - Interpret the results.

[a] Jeannette M. Wing: Computational Thinking, CACM, Vol. 49, No. 3, (2006)

## Example: Shipwrecked Sailors (Quiz in American. Newspaper 1926)

- 5 sailors strand on an island, collect coconuts and want to divide them next day. Go to sleep.
- First sailor wakes up, divides the nuts, one is left for the monkey, hides his part, shuffles the leftover together, goes back to sleep.
- The same repeats with the other sailors.
- Next morning, no one makes a remark, they divide the pile again, and again one nut is left for the monkey.
- How many nuts did they collect?

Solution:

- 1926 solve diophantine equation.
- Today: Simulate! Program the dividing process for nuts $n = 1, 2, 3, \ldots$ until a number is found which fulfills the conditions.

# Program: Shipwrecked Sailors

nuts

```
function [n,parts]=nuts;
n=0;                              % initialize number of nuts
good=0;                           % boolean variable
while ~good
  n=n+1;                          % try with next n
  leftover=n;
  good=1;                         % optimistic
  i=0;
  while (i<5) & good              % try to divide for all sailors
    good=rem(leftover,5)==1;      % good if one nut remains
    if good,
      i=i+1;                      % count sailor
      parts(i)=fix(leftover/5);   % saylor i takes his part
      leftover =parts(i)*4;       % shuffles the leftover together
    end
  end
  good=good & (rem(leftover,5)==1);% next morning:one nut left for monkey
  parts=(leftover-1)/5+parts;     % add morning share to each sailor
end
```

# Results

- ```
  >> [n,parts]=nuts
  n = 15621
  parts = 4147   3522   3022   2622   2302
  ```
- for the variant that no nut is leftover for the monkey in the morning we change

  ```
  good=good & (rem(leftover,5)==1); % next morning:one nut left for monkey
  parts=(leftover-1)/5+parts;       % add morning share to each sailor
  ```

  to

  ```
  good=good & (rem(leftover,5)==0); % next morning: no nut for monkey
  parts=leftover/5+parts;           % add morning share to each sailor
  ```

  and get

  ```
  >> [n,parts]=nuts
  n = 3121
  parts = 828   703   603   523   459
  ```
  ```

## Fractal

- $f(z) = z^3 - 1$ has 3 roots:

$$\zeta_1 = 1, \quad \zeta_2 = -\frac{1}{2} + \frac{\sqrt{3}}{2}i, \quad \zeta_3 = -\frac{1}{2} - \frac{\sqrt{3}}{2}i$$

- Apply Newton's Method to compute a root

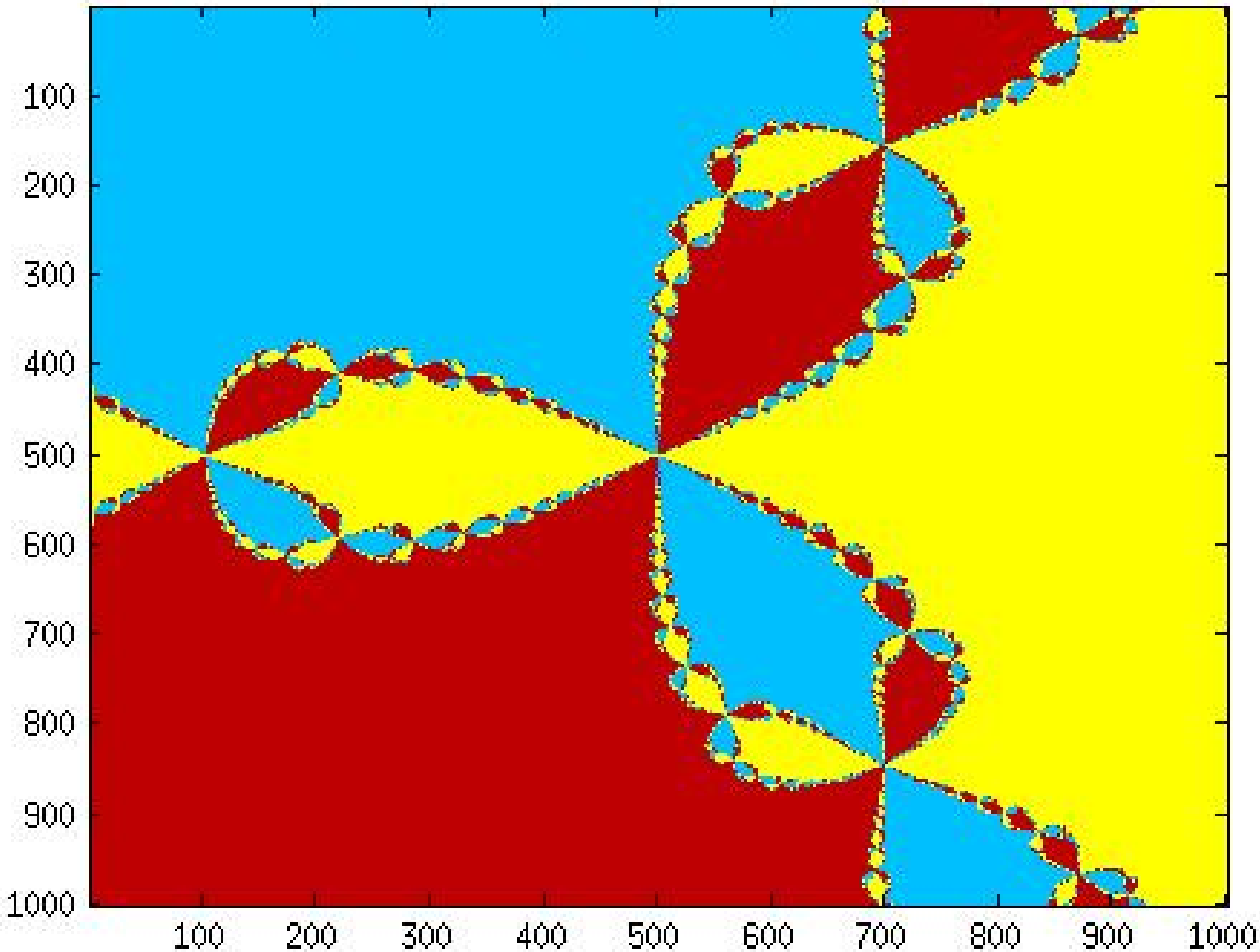
$$z_{k+1} = z_k - \frac{z_k^3 - 1}{2z_k^2}$$

- Basin of attraction for $\zeta_j = \{z_0 | \lim_{k\to\infty} z_k = \zeta_j\}$
- Compute points of basins for square $z = x + iy$ where $-1 \leq x, y \leq 1$

## Compute Basin of Attraction

fractal

```
clear,clf
n=1000; m=30;
x=-1:2/n:1;
[X,Y]=meshgrid(x,x);              % define grid for picture
Z=X+1i*Y;                         % initial values for iteration
for i=1:m
  Z=Z-(Z.^3-1)./(3*Z.^2);         % perform m iterations in parallel
end;
a=20;
image((round(imag(Z))+2)*a);      % transform roots to a,2a,3a
```


100
200
300
400
500
600
700
800
900
1000
100
200
300
400
500
600
700
800
900
1000

## Informatics as New Basic Subject in Schools?

- Opposition
  - No money. Crises in Europe. High unemployment rates.
  - Expensive: support, maintaining equipment, license fees
  - Policy makers often don't know what programming means. They also often don't know the difference between digital literacy (ICT) and informatics

    Why is ICT necessary? Kids learn the handling of the new devices anyway by themselves.

- Greek solution: eliminate ICT lessons from schools.

  Easy way to save money.

  Solution for poor countries? Resign and give up education in the essential technology for innovations?

## Alternative

- Training computational thinking and problem solving does not need expensive equipment .
- Inexpensive computer like Raspberry Pi for $ 25.–:
  `http://www.raspberrypi.org/`
- Public domain software is free of charge:
  - Linux operating system
  - LibreOffice (successor of OpenOffice)
    `http://www.libreoffice.org`
  - LaTeX for professional typesetting
  - Logo, Pascal, Octave, . . . programming languages

Google engineer Neil Fraser
(March 2013, visiting Vietnamese high school kids) [a]

- *Problem: "Given a data file describing a maze with diagonal walls, count the number of enclosed areas, and measure the size of the largest one."*
- *The class had 45 minutes to design a solution and implement it in Pascal. Most of them finished, a few just needed another five minutes. There is no question that half of the students in that grade 11 class could pass the Google interview process.*
- *If nothing else, this snapshot into the Vietnamese school system shows what can be done despite limited funds.*

[a] `http://www.theregister.co.uk/2013/03/22/vietnam_kids_google_interview_pass/`

## Final Comments and Recommendations

Report of Informatics Europe and ACM Europe:

- European nations are harming their primary and secondary school students, both educationally and economically, by failing to offer them an education in the fundamentals of informatics.
- Continuation of this failure would put the European economy at risk by causing students to lag behind those of many other countries, including emerging but increasingly competitive countries (India is the most obvious example but by far not the only one).
- Informatics education must become, along with digital literacy, an obligatory part of general education.

## Final Comments and Recommendations (cont.)

**Recommendation 1.** All students should benefit from education in digital literacy, starting from an early age and mastering the basic concepts by age 12. Digital literacy education should emphasize not only skills but also the principles and practices of using them effectively and ethically.

**Recommendation 2.** All students should benefit from education in informatics as an independent scientific subject, studied both for its intrinsic intellectual and educational value and for its applications to other disciplines.

## Final Comments and Recommendations (cont.)

**Recommendation 3.** A large-scale teacher training program should urgently be started. To bootstrap the process in the short term, creative solutions should be developed involving school teachers paired with experts from academia and industry.

**Recommendation 4.** The definition of informatics curricula should rely on the considerable body of existing work on the topic and the specific recommendations of the present report (section 4).

# There is Hope


# And Finally:

Money is not everything, but without money everything is nothing.

## There is Hope


## And Finally:

~~Money~~ Informatics is not everything, but without ~~money~~ informatics everything is nothing.