On Effective CS Education in the Era of Information Technology

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Roadmap

1. STEM Education
   - CS Enrollment

2. Several Initiatives
   - NSF: BPC-A and CE21 and ACM: CSTA

3. CS Curricula
   - ACM Curriculum and Competing Fields

4. On Creativity
   - Different Methodologies

   - Final Thoughts
1. STEM Education

**STEM:** Science, Technology, Engineering, and Math

![Graphs showing STEM employment growth and educational attainment by degree level.](image-url)
Education Level and Income Deciles

Computer Science: Majors and Jobs

Percentage of New STEM Jobs

- Computing: 71%
- Traditional Engineering: 16%
- Physical Sciences: 7%
- Mathematics: 2%
- Life Sciences: 4%
- Computer Networking: 21%
- Computer Support: 7%
- Database Admin.: 2%
- Systems Analysis: 10%
- Software Engineering: 27%
- CS/IS: 1%
- Other Computing: 3%

Source: CRA Taulbee Survey
2. Several Initiatives

- Broadening Participation in Computing Alliance (BPC-A)
  - BPC-A addresses issues across K-16

- Computing Education for the 21st Century (CE21)
  - Effective teaching and learning in computing
  - NSF-initiated CS 10K project: 10,000 high school teachers to teach AP exam in CS

- Cyberlearning: Transforming Education (CTE)
ACM: CSTA

- Computer Science Teachers Association (CSTA)
  - Evolved from ACM's K-12 task force
  - Working on revising the model curriculum
  - Computing education for students ages 5-18 (K-12)
- Learn from the successful stories of
  - National Science Teachers Association (NSTA)
  - National Council for Teachers of Mathematics (NCTM)
Challenges (1):

- Perception of CS as a service discipline
- Branding CS discipline in the era of big data
- Attaching more participants in CS STEM
3. CS Curricula

- Diversification of CS education
  - Past foundation
    - mathematical logic
    - mathematical engineering (M. Snir)
  - Current foundation
    - mathematics, statistics, cognitive sciences, social sciences, physical sciences, etc.

- New fields and cross-disciplinary programs
  - Cybersecurity, data analytics, AI, and IoT
  - Double major, CS-major X-minor, and X-major CS-minor
ACM (AIS and IEEE) Curricula

- Curriculum 65
  - Prelim. recommendation
- Curriculum 68
  - Algorithmic thinking
- Curriculum 78
  - Programming skills
- Curriculum 91
  - Multiple core
- Curriculum 01
  - Multiple tracks
- Curriculum 13
  - Outward looking

ACM Curriculum
- Computer Engineering
- Computer Science
- Information Systems
- Information Technology
- Software Engineering

Multiple Introductory Seq.
- Imperative-first
- Object-first
- Functional-first
- Algorithm-first
- Hardware-first
Sample Curricula: IST
CS Education Matters

**ACM Symp. on CS Education (SIGCSE 2018)**

- **Keynote:**
  - The Evolution Before the Revolution
  - Teaching CS in a Time of Opportunities and Challenges

- **Panel:**
  - Team-Teaching with Humanities; Rising CS Enrolments
  - Writing in CS: Why and How? Best Practices to Remedy Gender Bias

- **Special Sessions:**
  - Studying K-12 Computing Education
  - Evaluating CS4All Initiatives - Challenges and Opportunities
  - ACM Student Research Competition

- **BOF Flock:** CSTA: Connecting Colleges and K-12 CS Teachers

- **Technical Papers, Exhibits, Posters, Demos, and NSF Showcases**

- **ACM Journal of Educational Resources in Computing**

- **ACM Transactions on Computer Education**
Distributed Ed: Stanford “Intro to AI”

- S. Thrun (Stanford) and P. Norvig (Google)
- Free and online worldwide
- Delivering lectures on youtube
- Earning class certificate once passing

- Intro & complexity
- Tech trends
- Naming
- Enforcing modularity
- Operating systems
- Concurrency
- Threads
- Performance
- Networks
- Layers
- Routing
- End-to-end
- Sharing networks
- Distributed naming
- Fault tolerance
- Atomicity
- Recovery
- Isolation
- Multi-site atomicity
- Consistency and replication
- Security
- Message authentication
- User authentication
- Certification

F. Kaashoek (lecturer)

D. Katabi (recitation)
Diversity

CMU (School of Computer Science): Department, Institute, and Center
- Computer Science Dept.
- Human-Computer Interaction Institute
- Institute for Software Research
- Language Technologies Institute
- Lane Center for Computational Biology
- Machine Learning Department
- Robotics Institute

CMU Ph.D. Programs
- Computation, Organizations and Society
- Computational Biology
- Computer Science
- Human-Computer Interaction
- Language and Information Technologies
- Machine Learning
- Machine Learning and Public Policy
- Machine Learning and Statistics
- Robotics
- Software Engineering
The Bigger Picture

CS role in four scientific paradigms

- **Theory**: The primary scientific paradigm

- **Experimentation**: The use of apparatus, artifacts, and observation to test theories and construct models

- **Computation (1980s)**: A specialization of experimentation with tools focused around numerical techniques afforded by computers

- **Data-driven (2010s)**: data and the computational systems needed to manipulate, visualize, and manage large amounts of scientific data
Challenges (2):

- Expanding C&I curricula while maintaining its core
- Utilizing IT technology for effective teaching and learning
- Educating CS students in ways of thinking and problem solving, which characterizes CS
3. On Creativity

- Transformative research
  - A culture of creativity [2]
  - The science of creativity [3]

- Research institutions
  - Communication
  - Cooperation
  - Courage

[3] Time, Special Issue on The Science of Creativity
Human Brain

- Left brain
  - Logic
  - Analysis

- Right brain
  - Creativity
  - Imagination
Quality

- Originality
  - Reading literature
  - Writing own paper(s)

- Learn from artists
  - Abstraction
  - Imagination

Georgia O'keeffe
Why Picasso is Great

- Know how to make appropriate [abstraction](#) - very important in CS!

- Many CS students use excessive amounts of math to explain simple things!

Les Demoiselles
Learning From Leonardo

Overemphasis on utility can be the enemy of creativity

- Be curious, relentlessly curious
- Indulge fantasy
- Create for yourself
- Let your reach exceed your grasp

Lady with an Ermine
Imagination

- Extended Fibonacci seq. \((F_i = F_{i-1} + F_{i-2}, 1, 2, 3, 5, 8, 13,\ldots)\)
  - 2, 4, 6, 10, 16, 26, 42,\ldots
  - 4, 8, 12, 20, 32, 54, 86,\ldots
  - 8, 16, 24, 40, 64, 104, 168,\ldots

- Fibonacci seq. in *The Last Supper*: 1, 2, 3, 5, \ldots
**MOOC**: massive open online course
- Coursera, Udacity, and edX

**MOOC hype**
- The New York Times: 2012 became “the year of the MOOC”
- Expectations undergoing a wild swing

**General distance/online courses**

**Flipped classroom**
- Watching online outside classrooms
- Q & A inside classrooms
General Distance/Online Courses

Features
- Lecture capture
- Interactive pen display

Products
- Zoom Video Communication
- Panopto, Camtasia Studio, etc

According to a 2015 survey among American students [4]
- + 45% take more than one online course
- + 9% take all of the courses online
- + 36% take non-credit courses for personal learning

Mastery Learning [5]

- Students must achieve a level of mastery
  - (e.g., 90% on a knowledge test) before moving forward to learn subsequent information

Big Five Personality Traits

- **Openness** to experience
  - Inventive/curious vs. consistent/cautious

- **Conscientiousness**
  - Efficient/organized vs. easy-going/careless

- **Extraversion**
  - Outgoing/energetic vs. solitary/reserved

- **Agreeableness**
  - Friendly/compassionate vs. challenging/detached

- **Neuroticism**
  - Sensitive/nervous vs. secure/confident
Grit

- IQ
  - Ability alone does not bring about success in any field

- High Achievers
  - Ability combined with zeal and with capacity for hard labor

- Grit
  - Perseverance and passion

- Development of the grit scale[6]

Role of Library

- Library
  - Means both “book” and “free”

- Social infrastructure
  - Shape the way people interact

- For all groups of people
  - Small kids
  - Teenagers
  - College students
  - Adults
  - Senior citizens
Education for Building Character!

- Learning the lesson from the classical music world
- Musicianship with character
- Violinists
  - Past generation: Heifetz, Oistrakh, Menuhin, Kreisler, Elman...
  - Current generation: Perlman, Mutter, Vengerov, Bell, Chang...

- ACM International Collegiate Programming Contest (ICPC)
  - Shanghai Jiaotong University (3 time winners, tied 1st overall)
  - Zhejiang University (2011 winner)

- D. A. Patterson (CACM, 2005):
  Reflections on a Programming Olympiad
  - Putin met with the 2004 winner team
  - U.S. president met with football champions
Shanghai Kids
First class city, first class education

![Bar chart showing education performance of 15-year-olds in various countries and regions, 2009. The chart compares mean reading and maths scores, with China (Shanghai) leading in both categories.]
Amy Chua’s “Tiger Moms”

- **Time Magazine, Jan. 2011**
  - Is tough parenting really an answer?

- **NY Times, Jan. 15, 2011**
  - Chinese children typically start their formal education at age two
  - The Chinese tend to favour the U.S. education system for trying to make learning exciting and not just a chore

- **NY Times, Nov. 3, 2011**
  - The China Conundrum
  - It is difficult to identify good Chinese students from applications
Elite to Mass to Universal

- Almost all schools follow similar curricula
- Almost every child in China learns one classical musical instrument
  - ... but, there are only 2 or 3 thousand die-hard classical music fans in Beijing!
Conflicting Views on Education in U.S.

- Thomas L. Friedman: Five Pillars of Prosperities
  - Public education, modernization infrastructure, open immigration policy, basic R&D, and regulation of private economic activity
  
  (Three-time Pulitzer winner)
Conflicting Views on Education in U.S.

- The debate on “the need for higher education”
  - Bill Gates, Steve Jobs, and Mark Zuckerberg never completed their college study
Things Students Learn at College

50% of the learning materials for a student’s career future is outside the classroom.

45% show no significant gains in critical thinking, analytical reasoning, and written communication during the first 2 years.

BUT

- Learn how to learn
- Learn how to think
- Learn self-discipline
- Learn how to communicate effectively
U.S. Ed. System

- National priority
  - Public safety, transportation, energy, education, health, advanced manufacturing

- Admission criteria
  - Standardized test, GPA/HPA, extra-curricular activities, etc.

- Different types
  - Vocational technical institutions, community colleges, universities, and professional schools
Chinese System vs. U.S. System

- **Chinese system**
  - Highly structured, disciplined learning

- **U.S. system**
  - Critical thinking and student-centered learning

China and the U.S. should learn from one another and adopt what the other does best!
Merits of U.S. Ed. System

● U.S. system
  ○ Flexibility of educational system
  ○ Importance of extra-curricular activities
    ● Club activities
    ● Sports
    ● Volunteering

● Five pillars of learning
  ○ Learning to know
  ○ Learning to do
  ○ Learning to live together
  ○ Learning to be
  ○ Learning to transform oneself and society
Challenges (3):

- Developing general education to produce well-rounded citizens
  - Fulfilling individual potential AND
  - Contributing to social transformation
Final Thoughts

- **Education ecosystem**: government, industry, academia, and professional societies
Charles Darwin (Origin of Species)

“It’s not the strongest of the species that survives, not the most intelligent, but the one most responsive to change.”