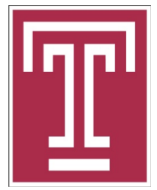


On Effective CS Education
in the Era of Information Technology

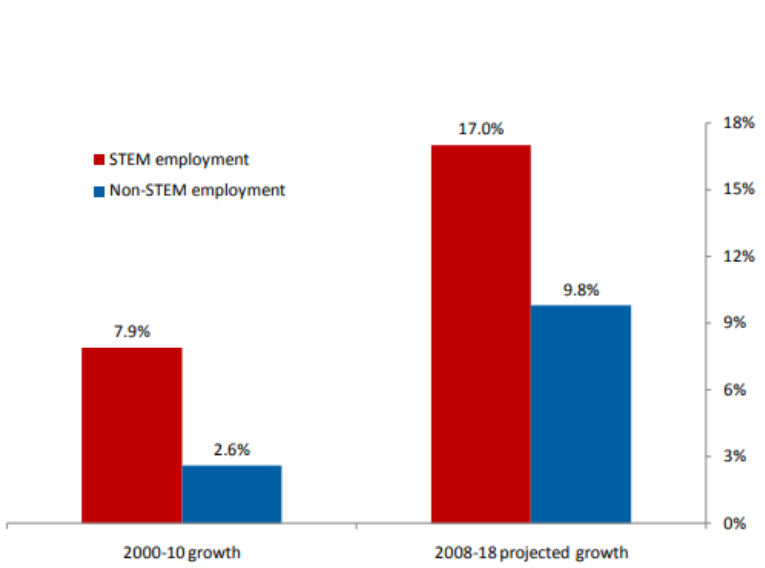
Jie Wu
Dept. of Computer and Info. Sciences
Temple University

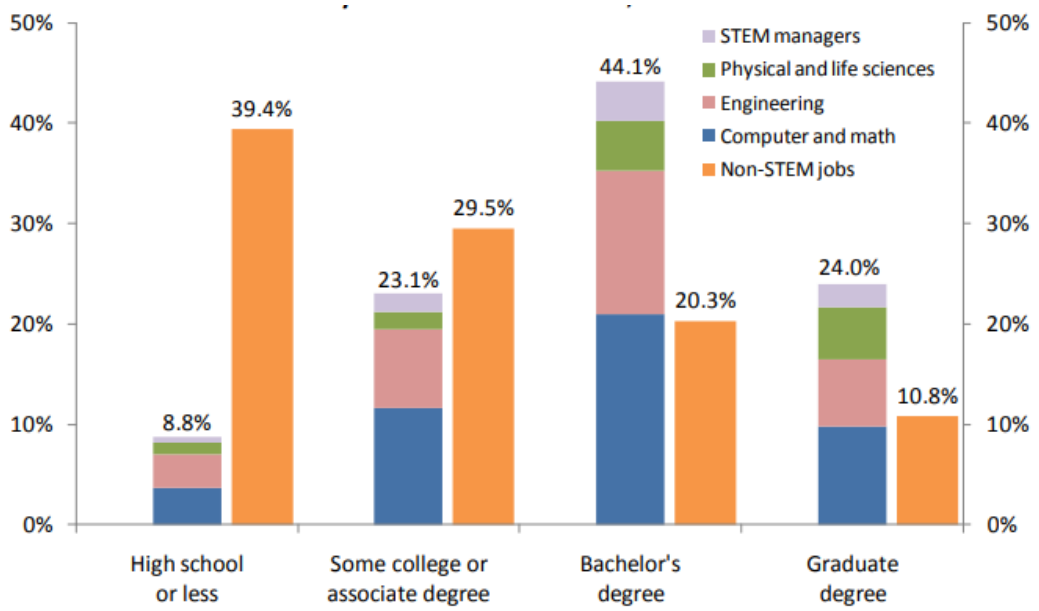
Roadmap

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
5. Chinese vs. U.S. Ed. Systems
   - Final Thoughts

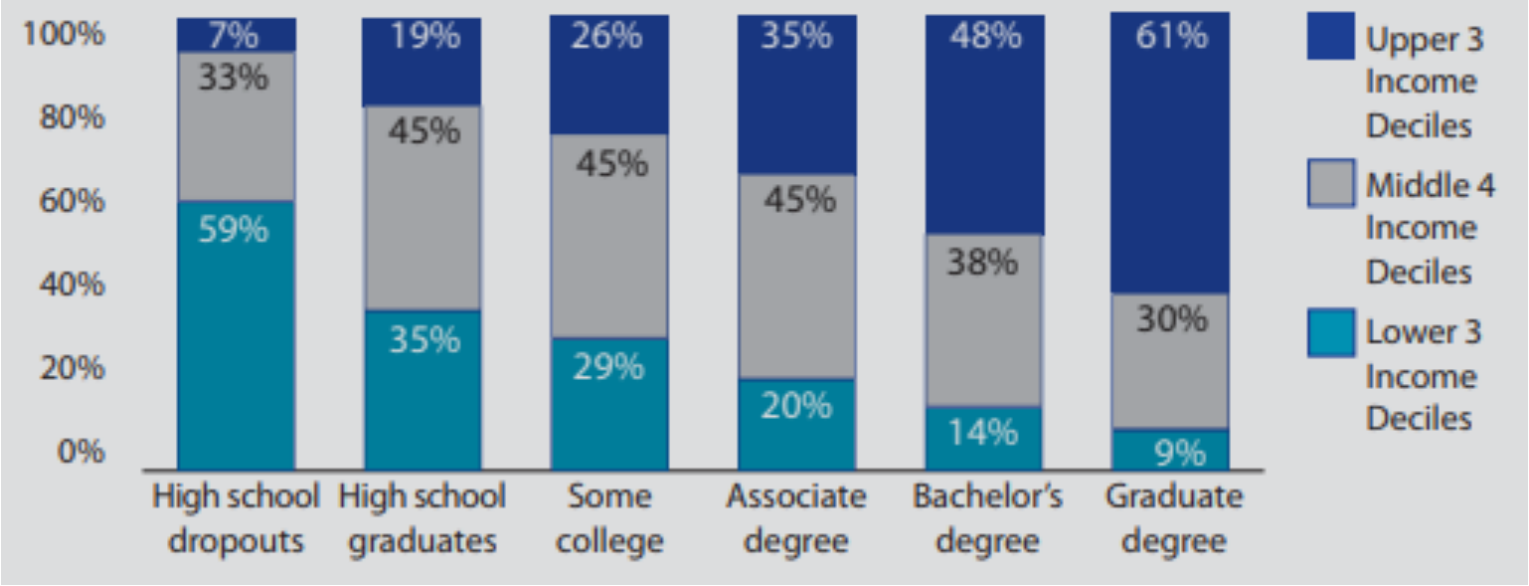
1. STEM Education

STEM: Science, Technology, Engineering, and Math



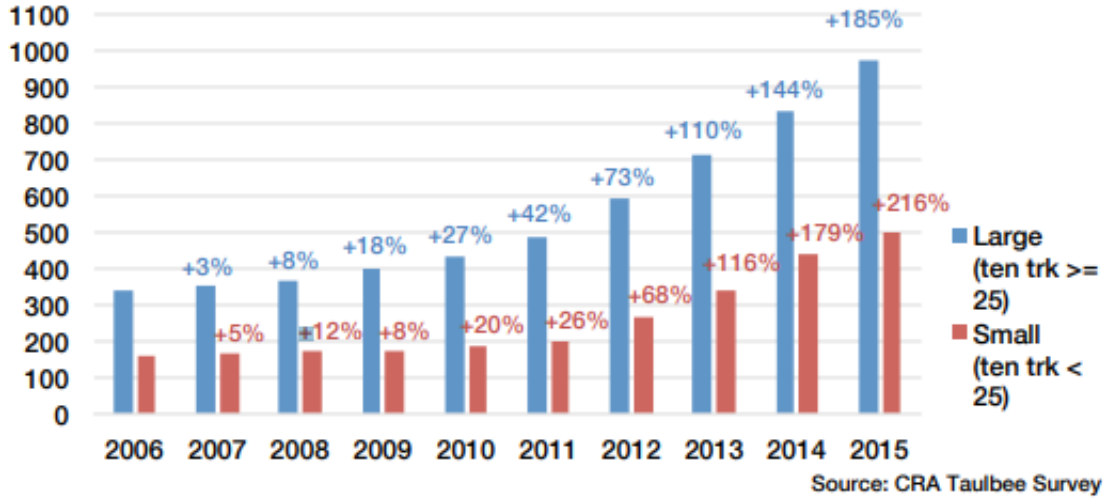


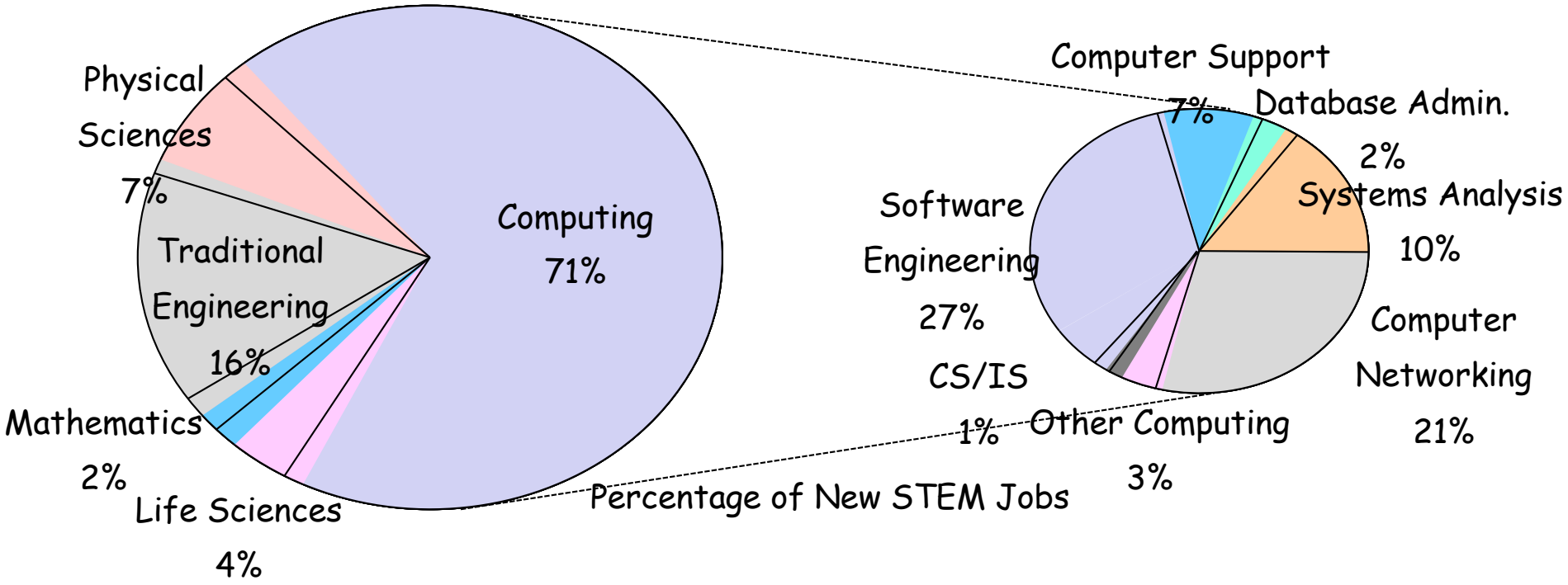
Education Level and Income Deciles [1]



[1] A. P. Carnevale (2010) "Help Wanted: Projection of Jobs and Education Requirement through 2018," Georgetown University.

Computer Science: Majors and Jobs





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,

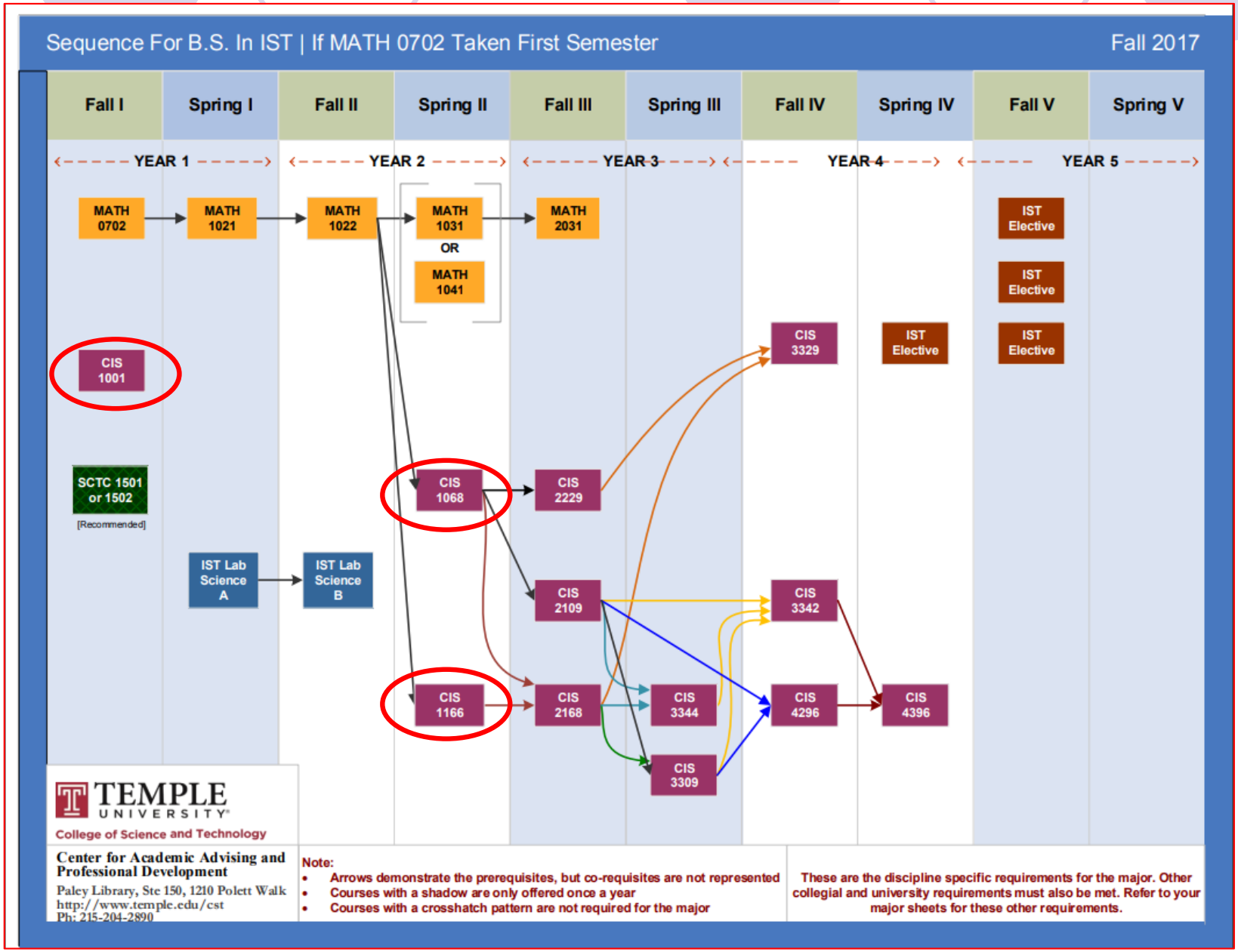
    social sciences, physical sciences, etc.
- New fields and cross-disciplinary programs
  - Cybersecurity, data analytics, AI, and IoT
  - Double major, CS-major X-minor, and X-major CS-minor

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

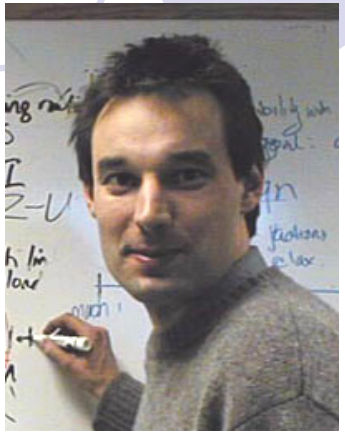
Distributed Ed: Stanford "Intro to AI"

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

STANFORD UNIVERSITY

Multi-subject: MIT "Computer Sys. Eng."

- 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

Carnegie Mellon

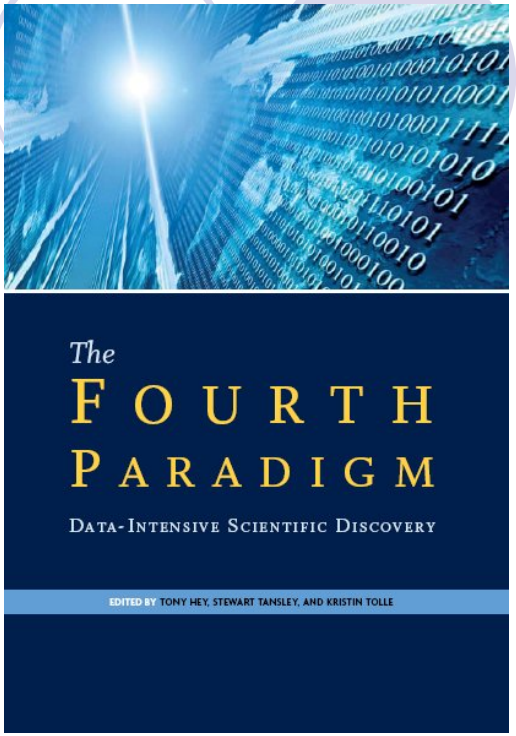
CMU (School of Computer Science): Department, Institute, and Center

- 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



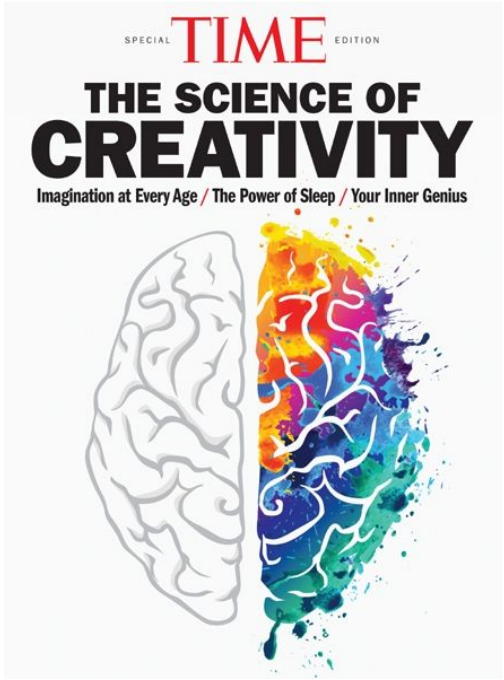
- CS role in four scientific paradigms
  - Theory: The primary scientific paradigm
  - Experimentation: The use of apparatus, artifacts, and observation to test theories and construct models
  - Computation (1980s): A specialization of experimentation with tools focused around numerical techniques afforded 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



[2] Alexander Von Humboldt Foundation, Cultures of Creativity

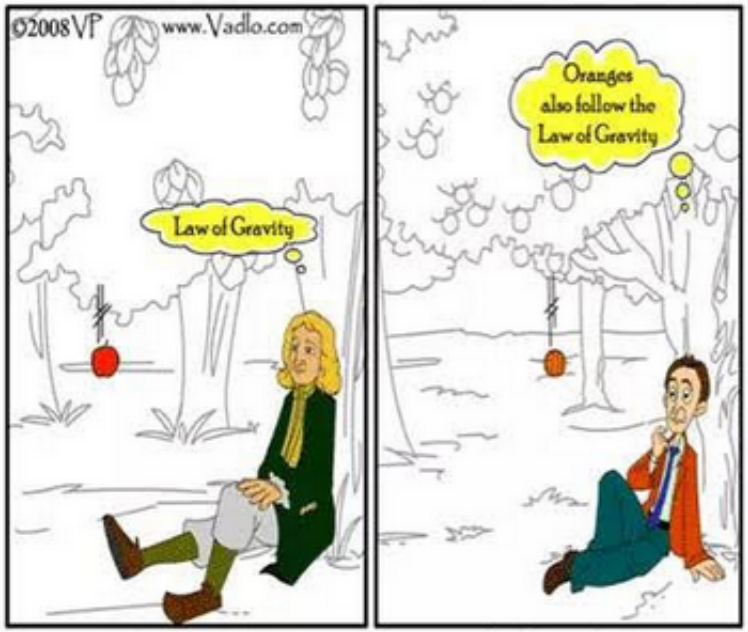
[3] Time, Special Issue on The Science of Creativity

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

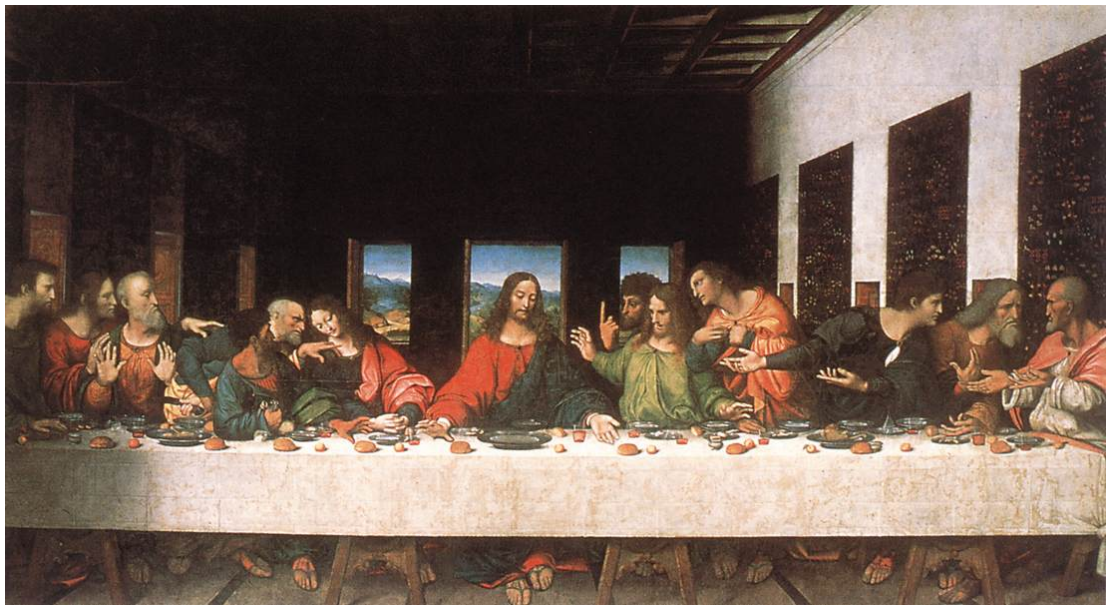
Overemphasis on utility can be the enemy of creativity

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

Lady with an Ermine

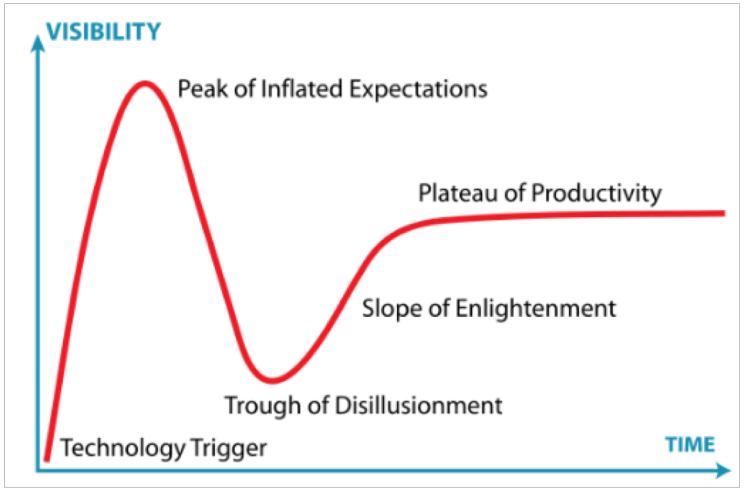
Imagination

- Extended Fibonacci seq. ($F_i = F_{i-1} + F_{i-2}$, 1, 2, 3, 5, 8, 13,…)
  - 2, 4, 6, 10, 16, 26, 42,…
  - 4, 8, 12, 20, 32, 54, 86,…
  - 8, 16, 24, 40, 64, 104, 168, …
- Fibonacci seq. in *The Last Supper*: 1, 2, 3, 5, …



MOOC

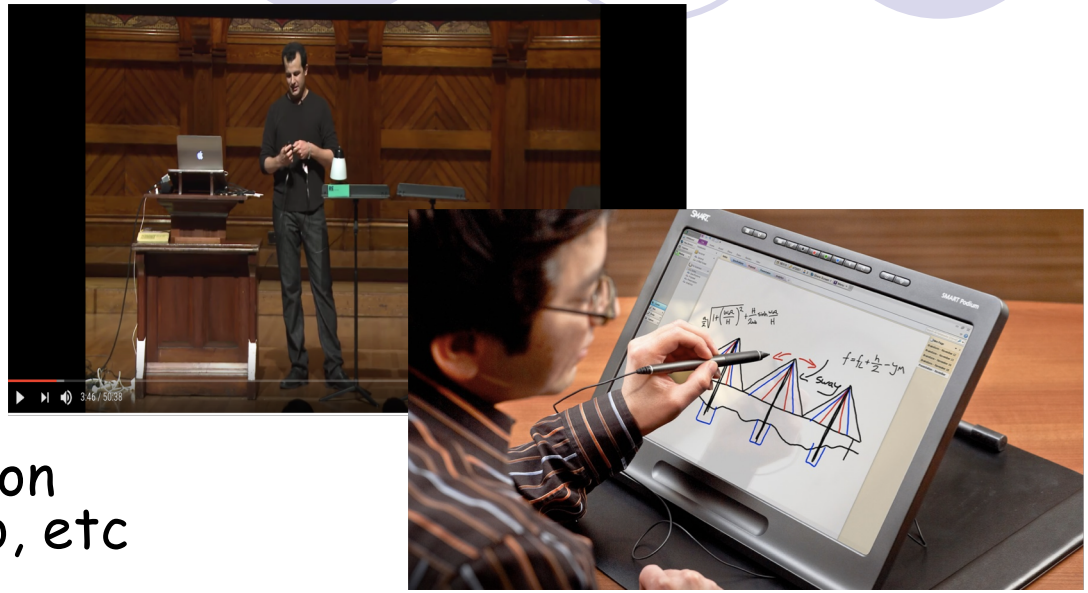
- MOOC: massive open online course
  - Coursera, Udacity, and edX
- MOOC hype
  - The New York Times: 2012 became "the year of the MOOC"
  - Expectations undergoing a wild swing
- General distance/online courses
- Flipped classroom
  - Watching online outside classrooms
  - Q & A inside classrooms



General Distance/Online Courses

Features

- Lecture capture
- Interactive pen display



Products

- Zoom Video Communication
  Panopto, Camtasia Studio, etc

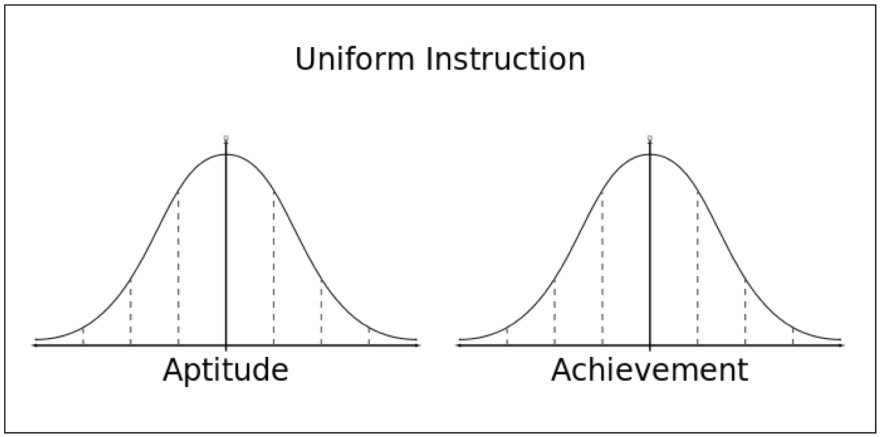
According to a 2015 survey among American students [4]

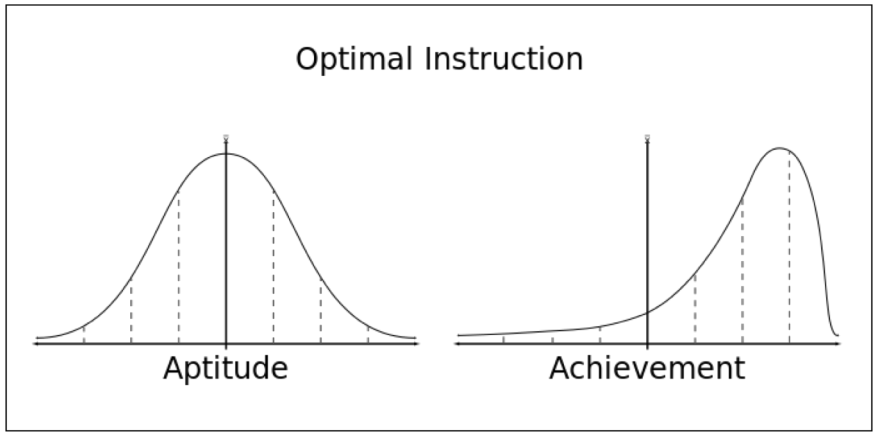
- + 45% take more than one online course
- + 9% take all of the courses online
- + 36% take non-credit courses for personal learning

[4] Babson College Survey in 2011

Mastery Learning [5]

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

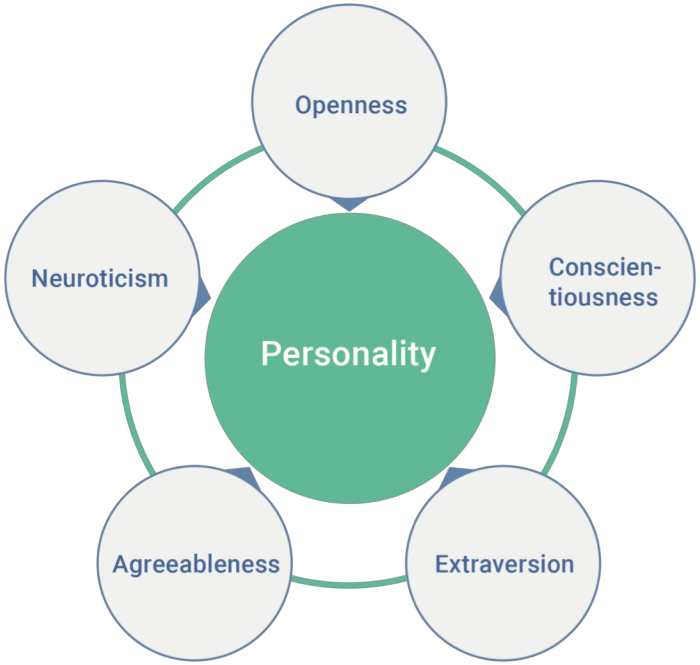




[5] B. S. Bloom (1981). *All Out Children Learning – A Primer for Parents, Teachers, and Other Educators*. McGraw-Hill.

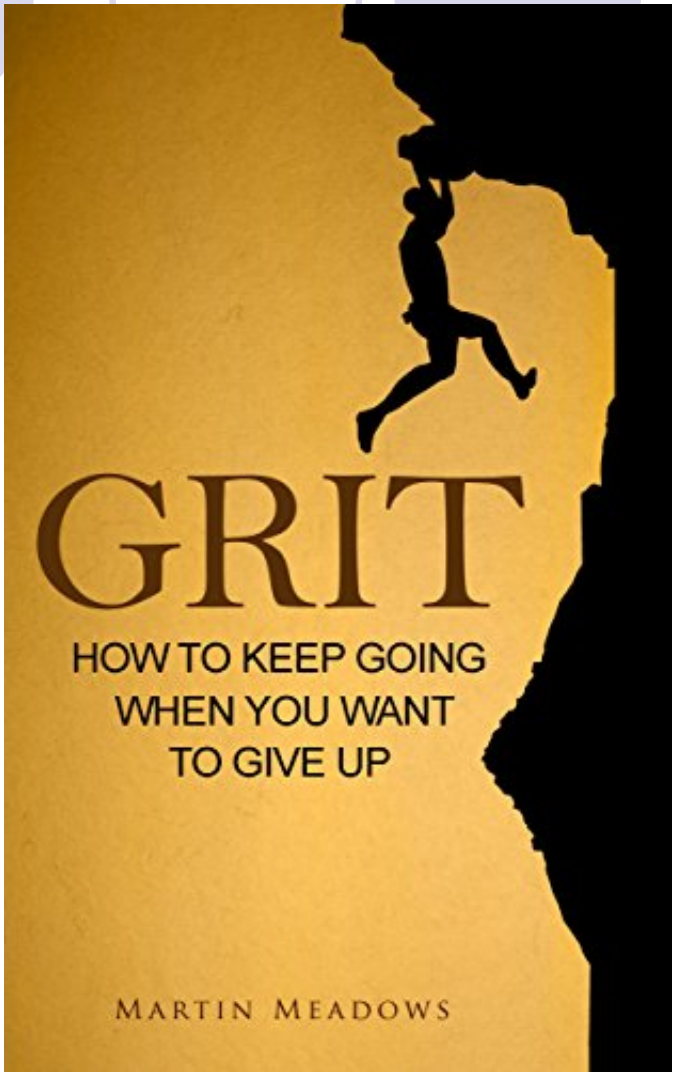
Big Five Personality Traits

- 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]



[6] M. D. Matthews (2007), Grit: Perseverance and Passion for Long-Term Goals, Journal of Personality and Social Psychology.

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…



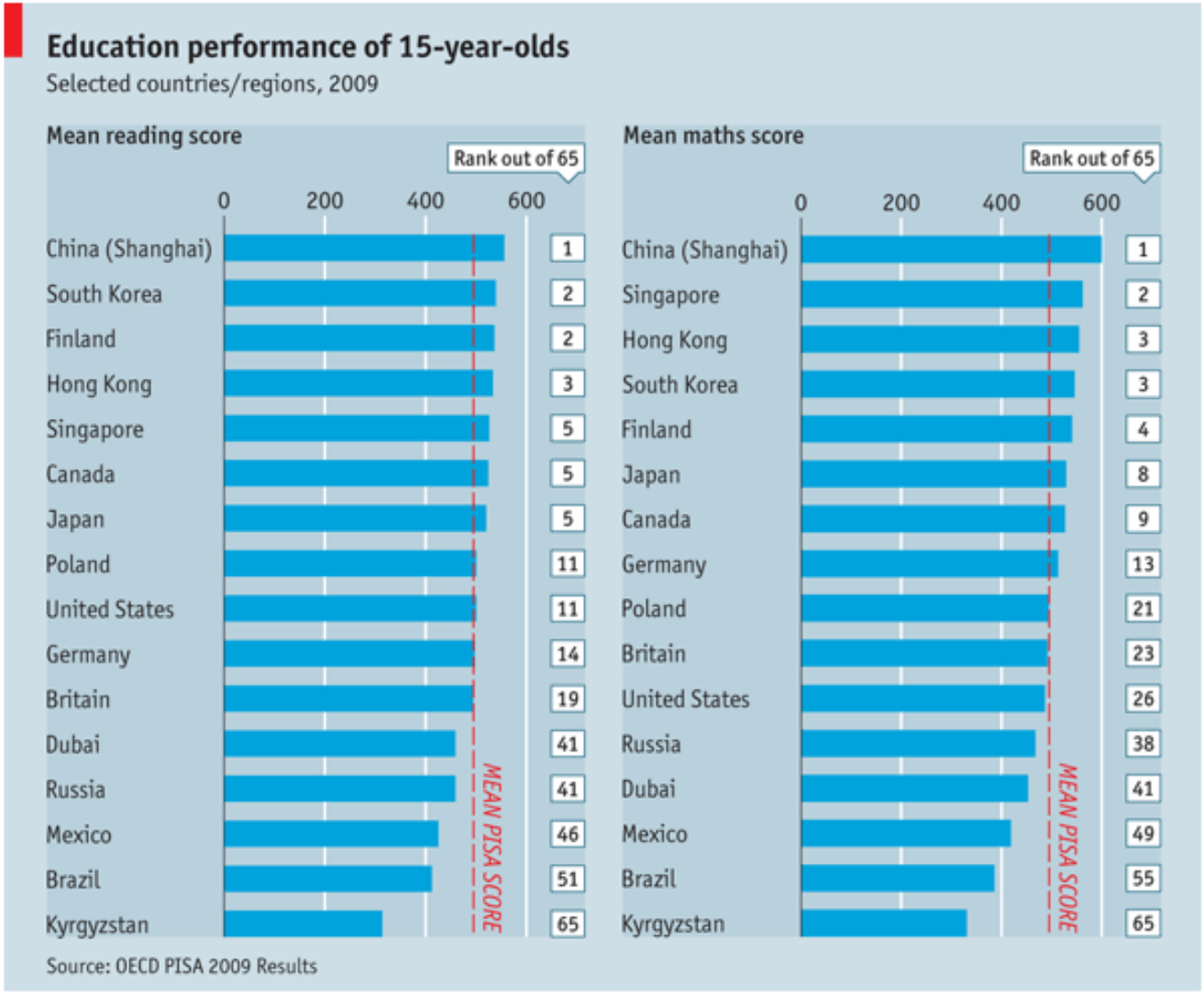


5. Chinese vs. U.S. Ed. Systems

- 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

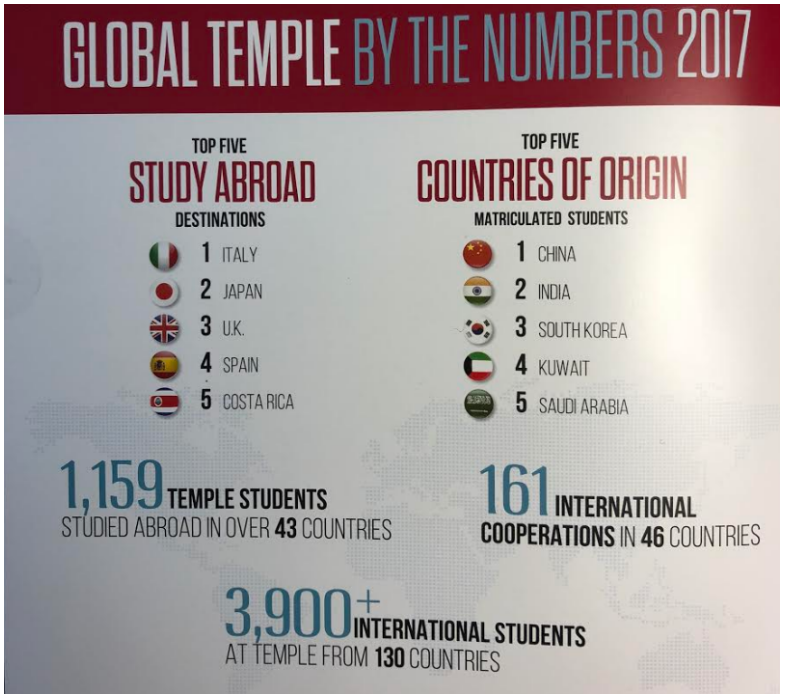
Shanghai Kids

First class city, first class education



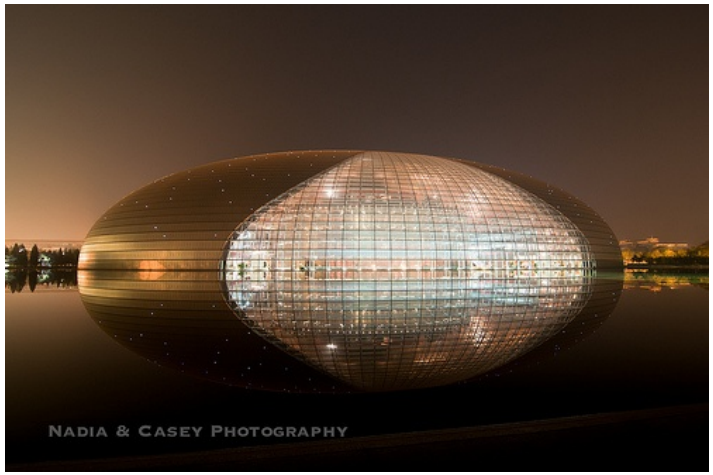
Amy Chua's "Tiger Moms"

- 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



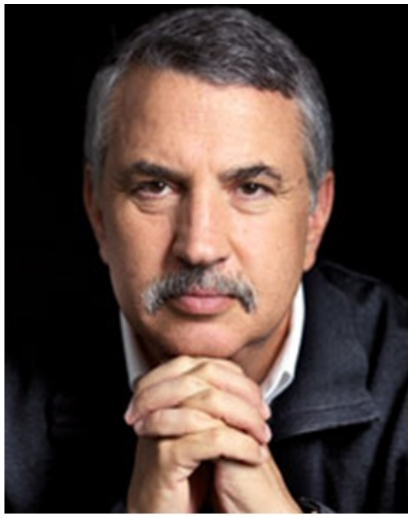
Elite to Mass to Universal

- 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!

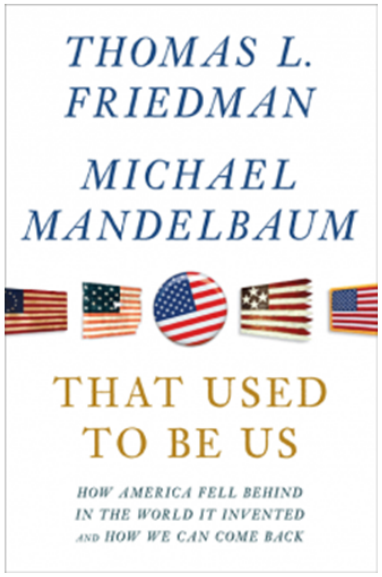


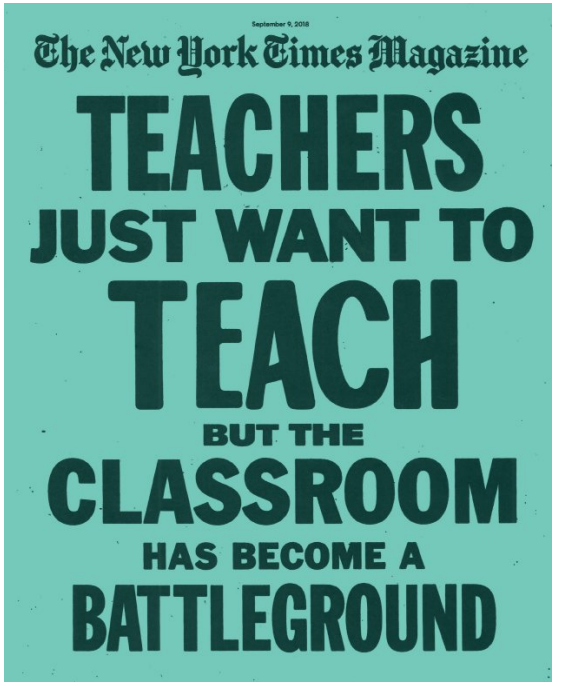
Conflicting Views on Education in U.S.

- Thomas L. Friedman: Five Pillars of Prosperities
  - Public education, modernization infrastructure, open immigration policy, basic R&D, and regulation of private economic activity



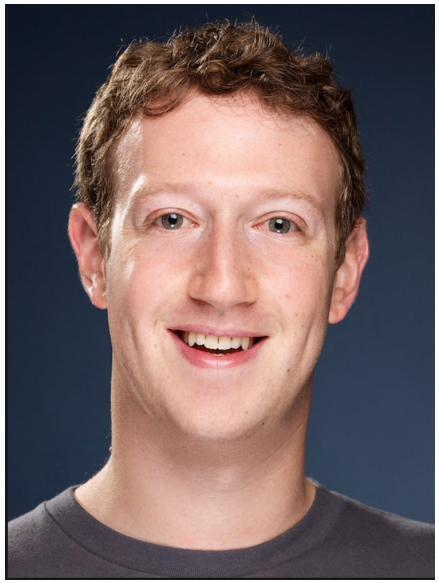
(Three-time Pulitzer winner)





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

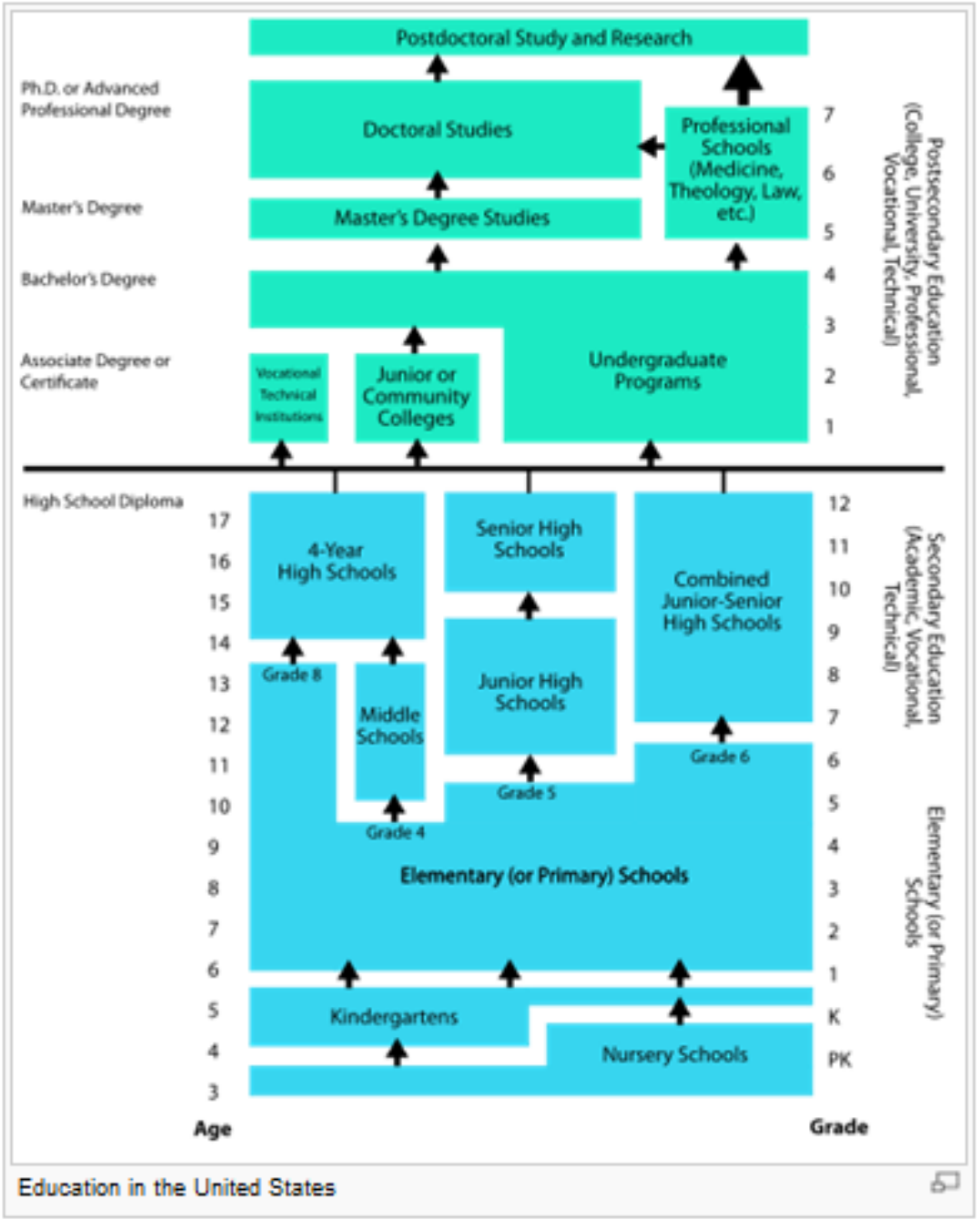
45% show no significant gains in critical thinking, analytical reasoning, and written communication during the first 2 years

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

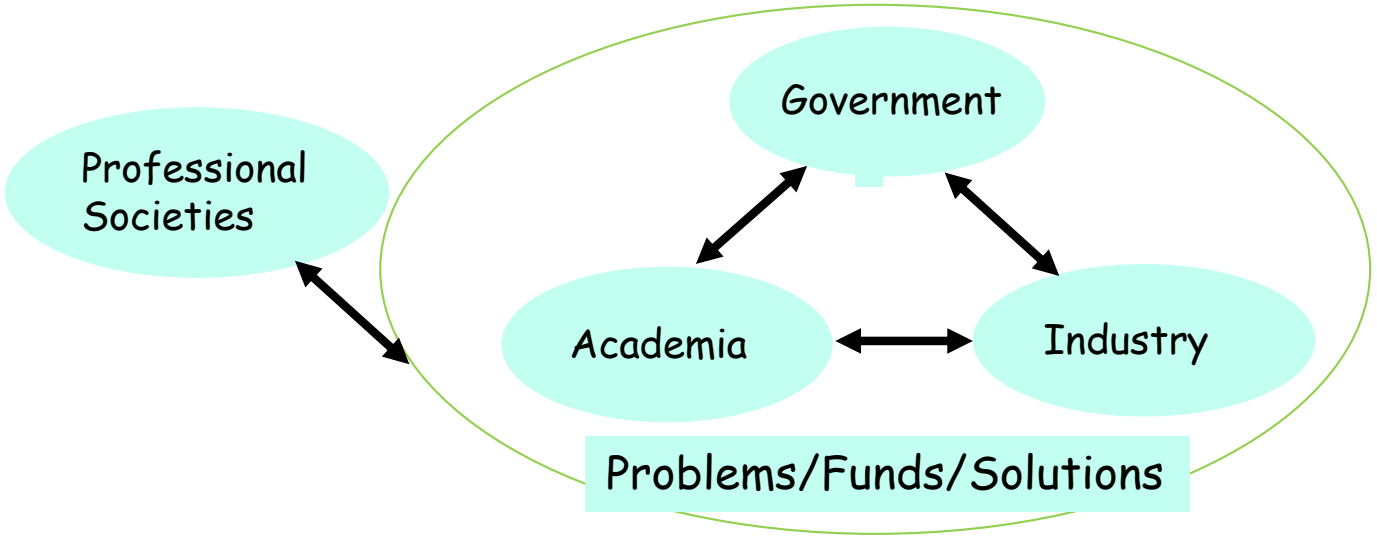
- U.S. system
  - Flexibility of educational system
  - Importance of extra-curricular activities
    - Club activities
    - Sports
    - Volunteering
- Five pillars of learning
  - Learning to know
  - Learning to do
  - Learning to live together
  - Learning to be
  - Learning to transform oneself 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."