AN OVERVIEW OF THE NATIONAL ACADEMIES STUDY ON GROWTH IN UNDERGRADUATE COMPUTER SCIENCE ENROLLMENT

Jodi Tims, Ph.D.

Professor and Chair

Baldwin Wallace University

The National Academies of

SCIENCES·ENGINEERING·MEDICINE

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STATEMENT OF TASK: PART I

- Investigate current and projected patterns of enrollment in undergraduate courses in computer science, computer engineering (CE), and information (within undergraduate information schools), including an analysis of the factors that have driven recent growth and may drive future growth.
  - Data will be disaggregated by type of 4-year institution (e.g., top 50, R-1).
  - The study will include an analysis of enrollment patterns among CS/CE/information majors and minors and science, technology, engineering, and math (STEM) and non-STEM majors taking service courses offered by CS/CE/information departments or enrolling in CS/CE/information courses on an elective basis.
  - A primary goal of this effort is to determine whether the recent increases in enrollment are similar to other cyclic fluctuations that have occurred in the past or whether they are more likely to be sustained.

STATEMENT OF TASK: PART II

- Investigate strategies that various institutions are using to respond most effectively to enrollment growth while maintaining or enhancing course access as well as the quality of instruction, considered by type of college or university.
  - The study will examine the impacts those strategies are having on CS/CE/information departments in terms of, for example,
    - faculty and graduate student hiring and workload (including non-CS faculty),
    - student retention, and
    - support for the needs of different categories of students (such as non-CS majors, CS minors, STEM majors, and non-STEM majors).

STATEMENT OF TASK: PART III

- Investigate the impact of enrollment growth on efforts to increase the enrollment of women and under-represented minorities in CS/CE/information courses and degree programs, as well as on strategies for retaining those students in the CS/CE/information field and encouraging their pathways toward graduate degrees and careers in related fields.

PUBLIC WORKSHOP

- Centrality and Dimensions of Computing
- Workforce Trends and Industry Needs
- The Impact of Enrollment Management Strategies on Diversity in Computing
- The Role and Future of Computing in Universities
- All presentations from the workshop are available at http://sites.nationalacademies.org/CSTB/CurrentProjects/CSTB_173432

Exploring the Capacity Problem

Eric Roberts
Charles Simonyi Professor of Computer Science, *emeritus*
Stanford University

The Capacity Problem in a Nutshell

- Employers cannot hire enough good software developers. This situation is likely to continue for the foreseeable future.
- Student interest in computer science—for both majors and nonmajors—has skyrocketed over the last decade.
- The low production rate of Ph.D.s in computer science and the attractiveness of industry make academic hiring difficult.
- Computer science departments have not been able to expand quickly enough to meet the student demand.
- Rising enrollments coupled with an inability to hire increase the workload pressure facing existing faculty.
- The current situation is unsustainable.
- "If something is unsustainable, it will stop." —Stein's Law

Critical Observations

- To meet the challenges facing academic computer science, several of us on the National Academies Committee believe it is imperative to recognize the following facts:

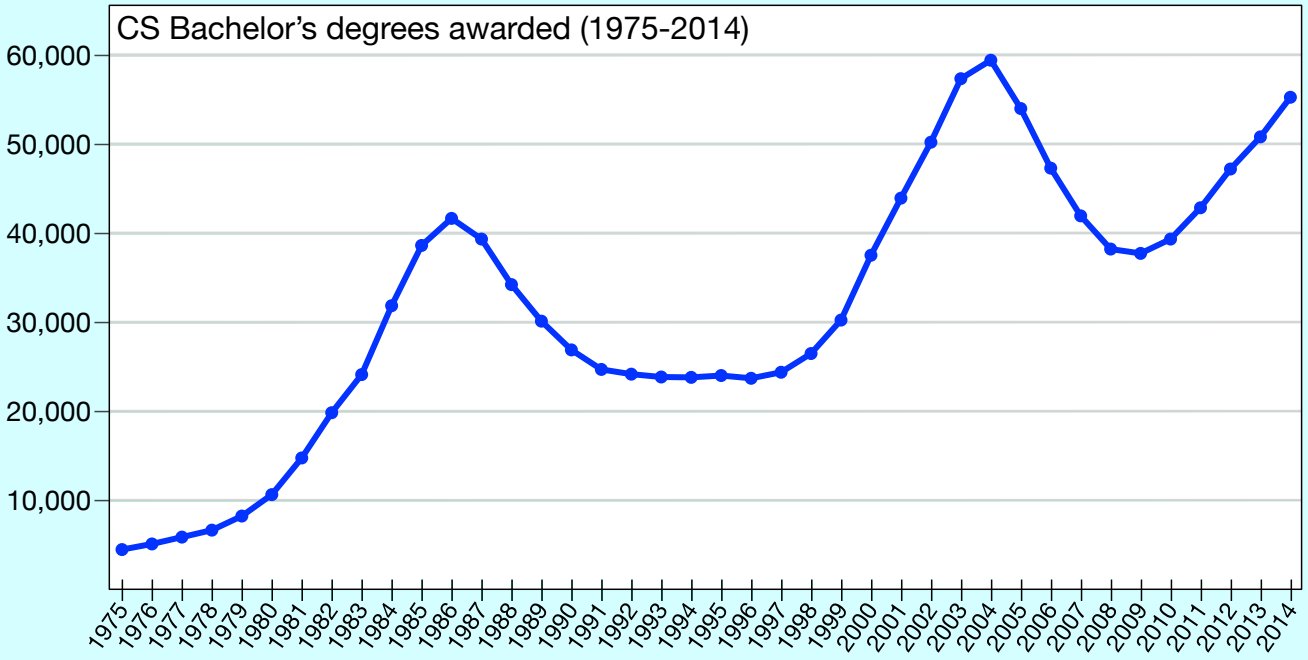
  1. Past declines in CS degrees *are not* caused by employment reductions. Employment has risen quickly and steadily.
  2. Although student reaction to the dot-com bust and offshoring were factors in the decline of the early 2000s, institutional actions to limit student enrollment played a major role in both of the earlier declines. Institutions take such actions when they cannot hire enough faculty to meet student demand.
  3. Beyond restricting the supply of workers for a vital sector of the economy, enrollment limitations have profoundly negative effects on student diversity.

Observation #1

Past declines in CS degrees *are not* caused by employment reductions. Employment has risen quickly and steadily.

Degree Production Has Been Cyclical

- Historical data show unequivocally that the number of CS degrees has risen and fallen sharply at various times in the past.



Source: National Center for Education Statistics, IPEDS database.

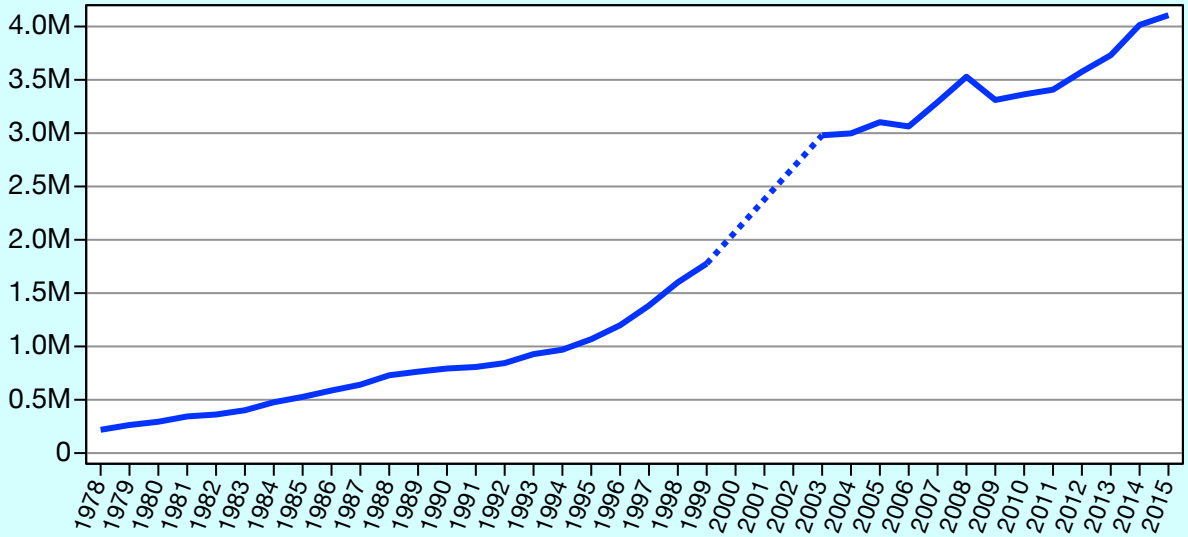
Misconceptions about Past Cycles

> *That the reduction in majors was due to reduction in workforce demand . . . is so widely assumed, that there may actually be little evidence associated with the conclusion.*
>
> —Professor David Culler, UC Berkeley

- Unfortunately, there is little common understanding about why such variations occur. The most widespread misconceptions are
  - That degree production tracks employment after a lag.
  - That declines in majors necessarily reflects student choice.
- No one on the National Academies Committee has been able to find any statistically significant data that support either of these claims.
- The persistence of these mythologies makes it difficult for CS departments to convince university administrations of the need to increase support. In such cases, fears of a coming downturn become a self-fulfilling prophecy.

Employment Growth Has Been Steady

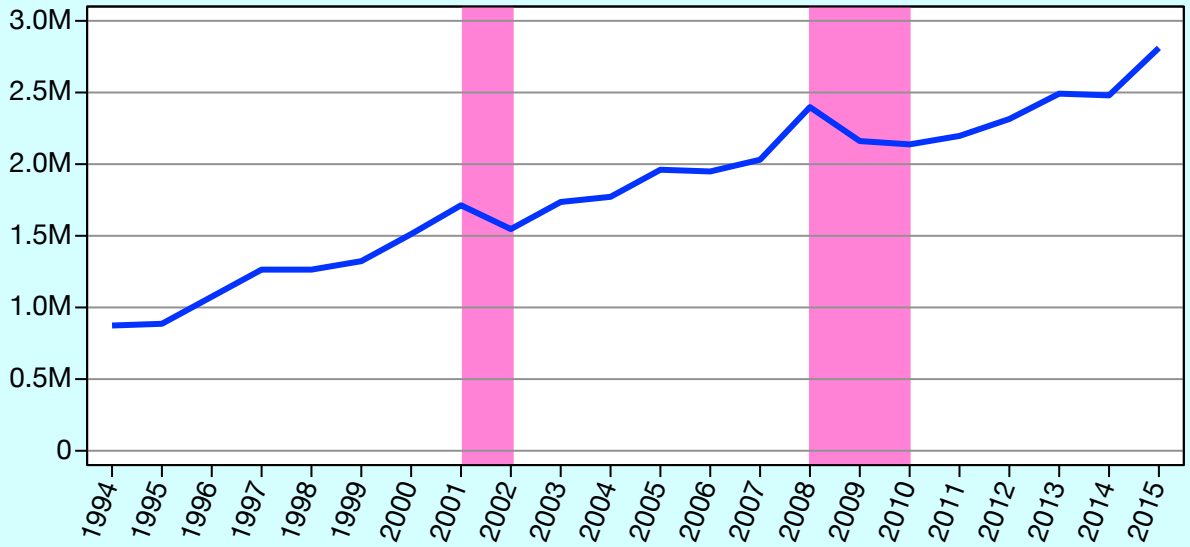
- Data from the Bureau of Labor Statistics show that employment in computing has risen by almost a factor of 20 since 1978.
- Unfortunately, statistics from the period covering the dot-com collapse are unavailable because of changes in classification.



Source: Bureau of Labor Statistics.

Recovering the Missing Years

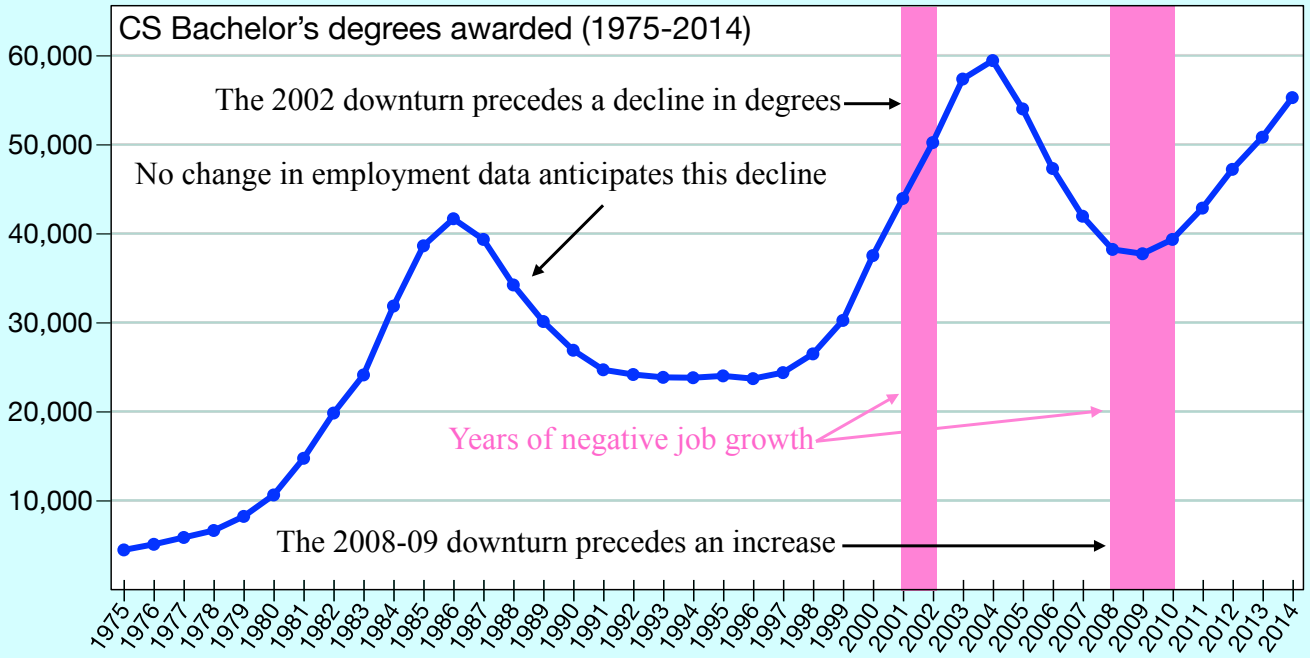
- Research by John Bound and Nicolas Morales eliminates the gap by comparing data from subfields that did not change.
- This graph shows that employment declined by more than 1% in only three years: 2001, 2008, and 2009.



Source: Bound and Morales, "Workforce Trends in Computer Science," August 2016.

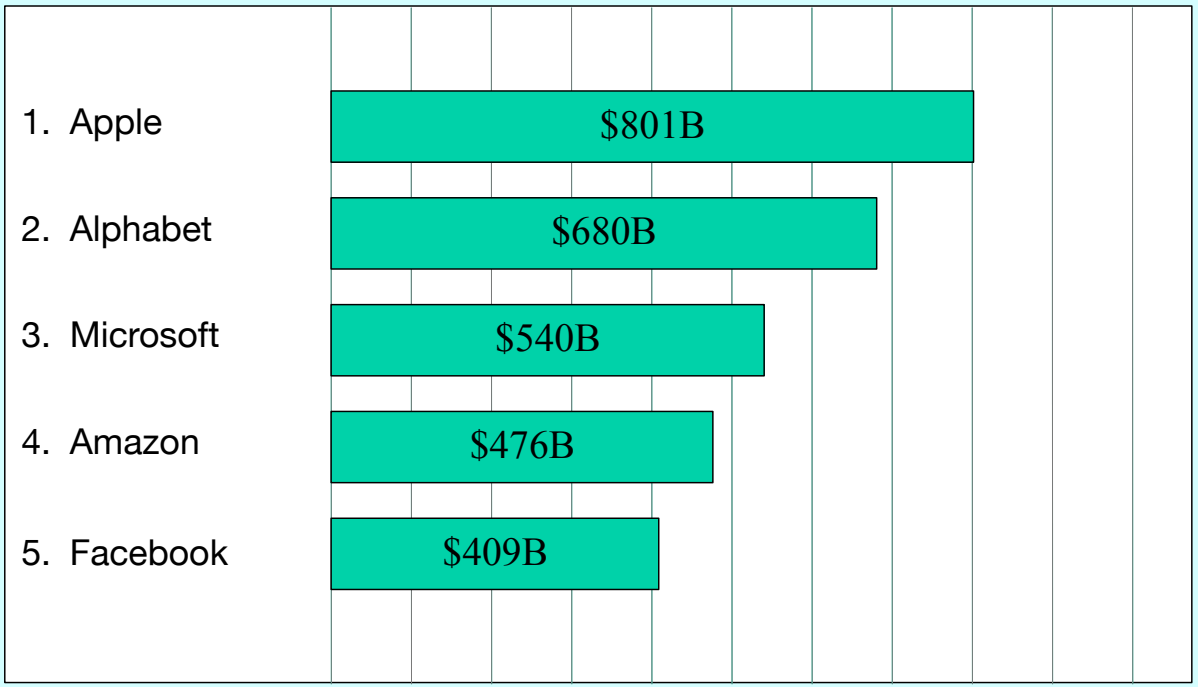
Downturns Have Inconsistent Effects

- Overlaying job growth data on top of degree production shows that labor market downturns are as likely to precede increases in degree production as declines:

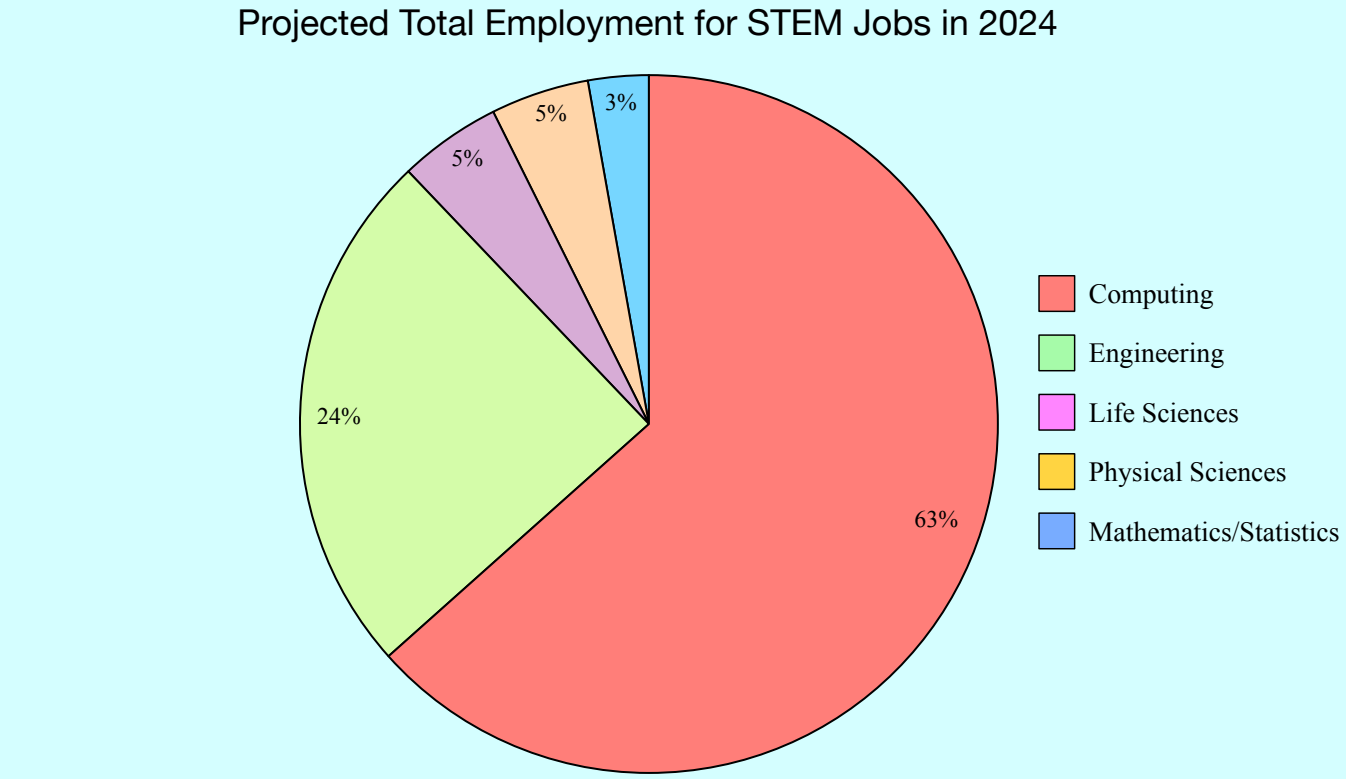


Computing Is Still Hot

- The top-ten industrial corporations by market capitalization: 2017

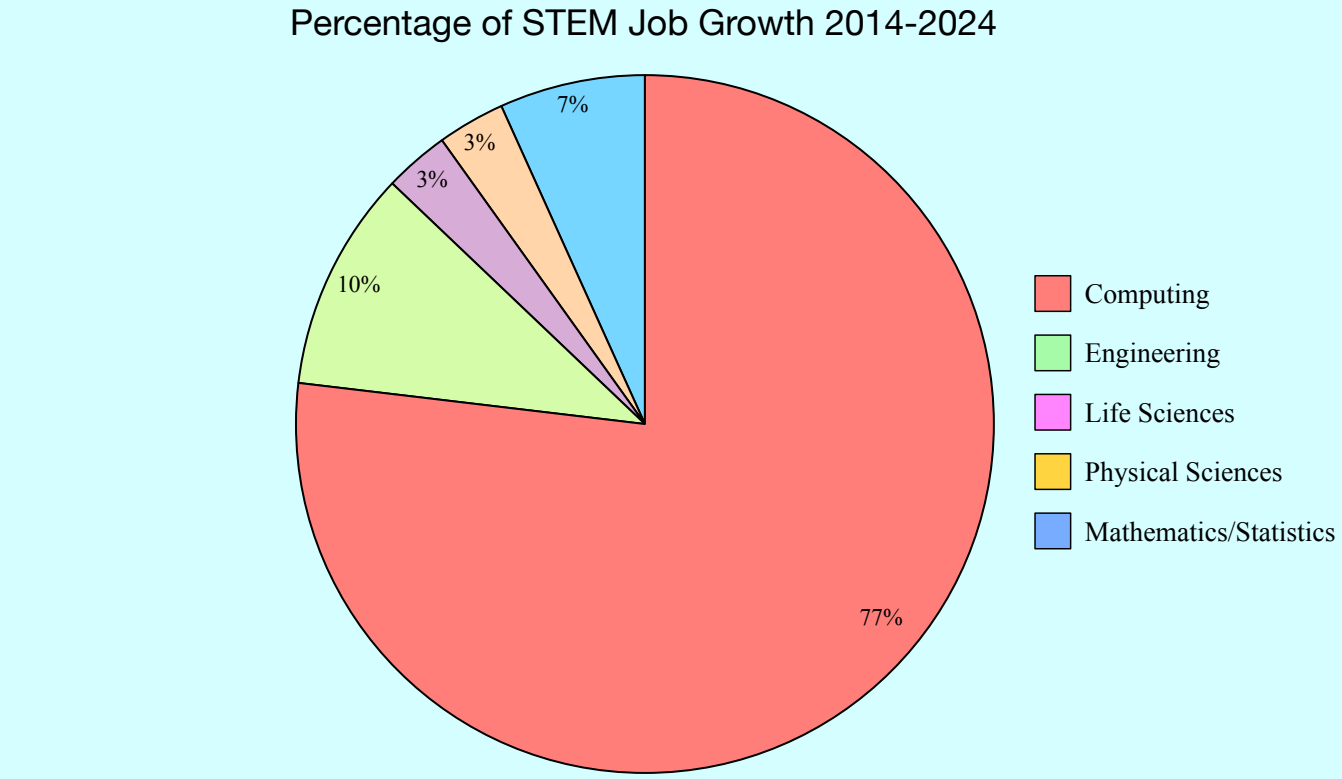


BLS Data Show Strong Job Growth



Source: Bureau of Labor Statistics 2014-2024 projections.

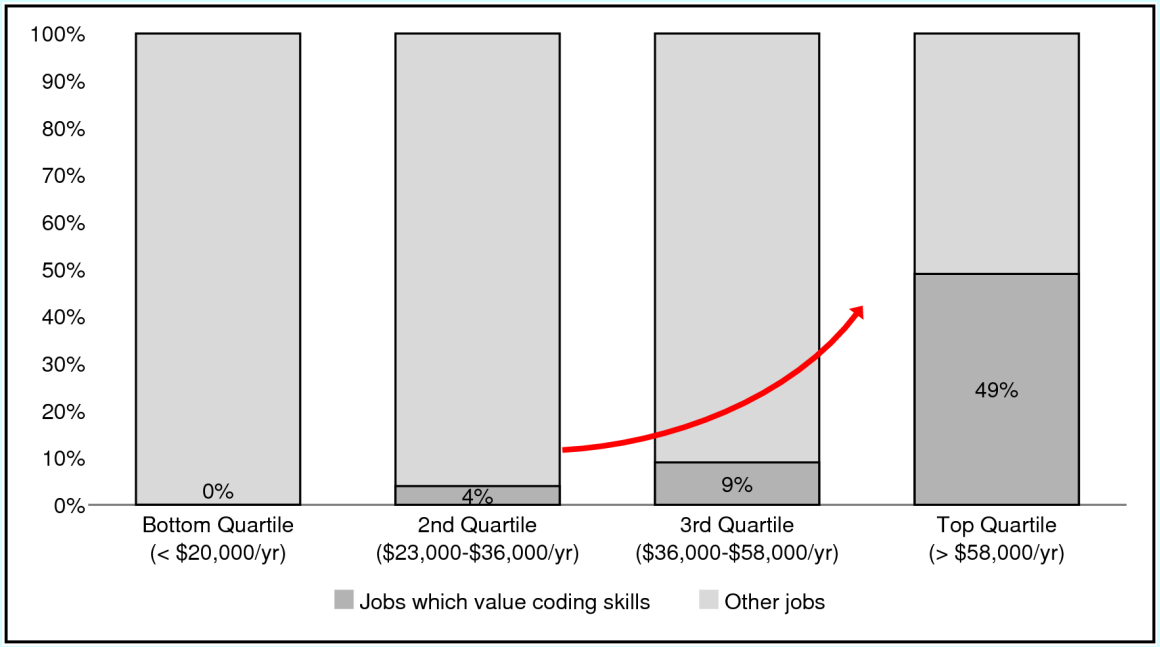
Computing Will See the Fastest Growth



Source: Bureau of Labor Statistics 2014-2024 projections.

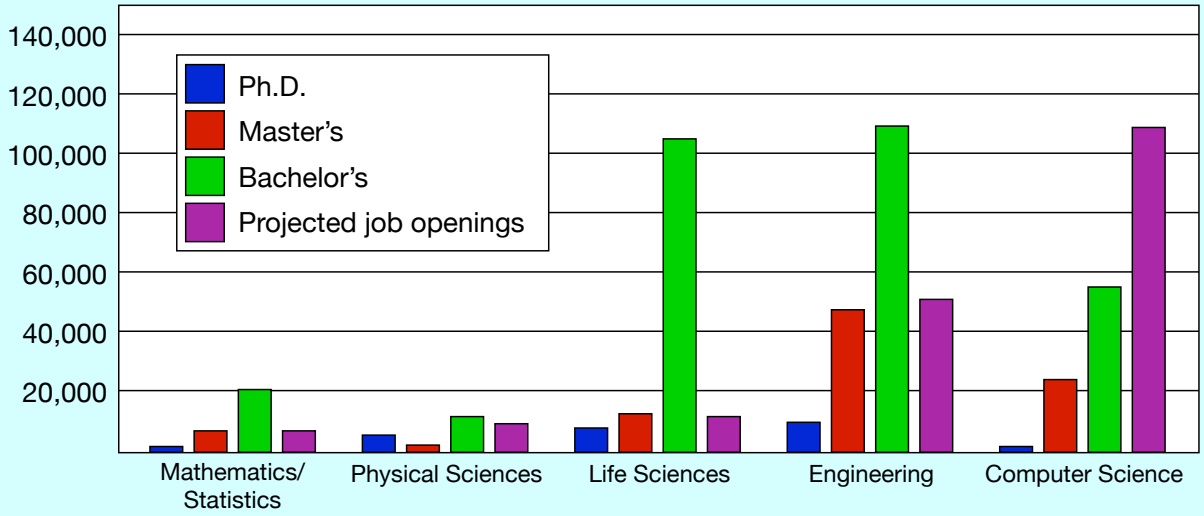
Computing Is Important for Better Jobs

- The demand for coding skills rises with income. Coding skills are almost nonexistent in the lower income quartiles, but half of all top-quartile jobs require the ability to code.



Source: Burning Glass Technologies, *Beyond Point and Click,* June 2016.

Degree Production Falls Short

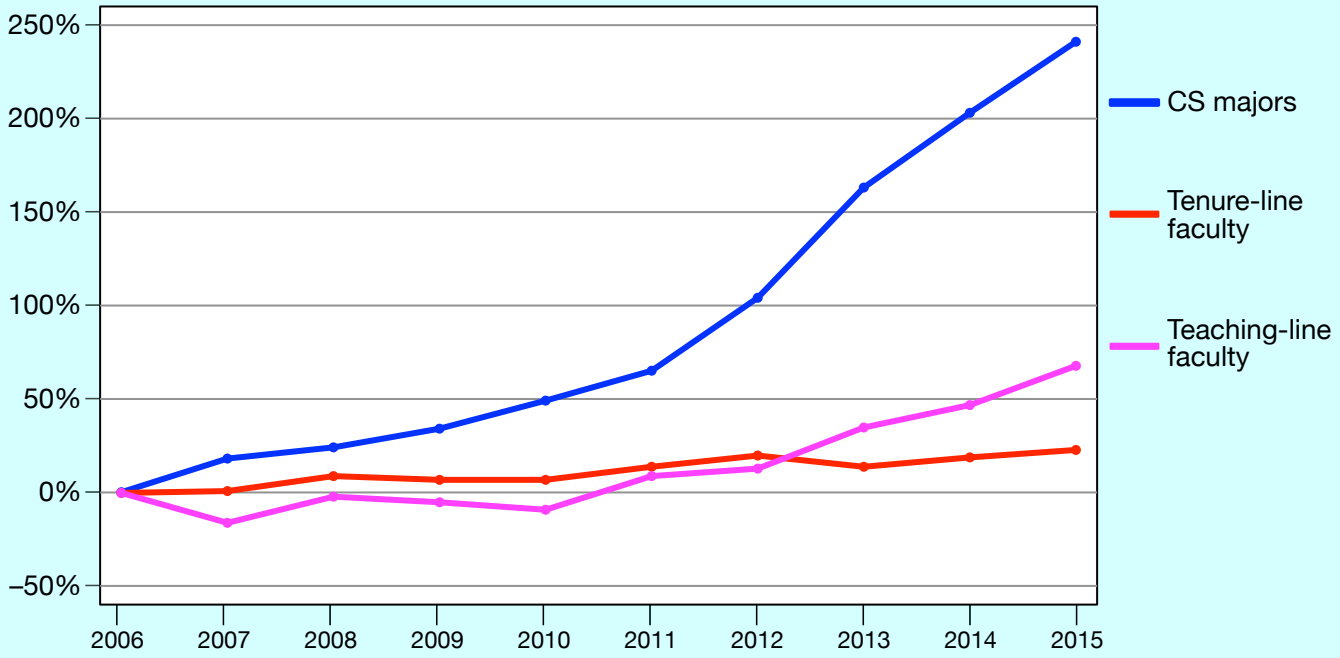


- Computing is the only major sector of the economy in which the number of jobs exceeds the supply of people with degrees.

Sources: Degree data from the National Center for Education Statistics 2014; projected annual job openings from the Bureau of Labor Statistics 2014-2024 projections. The idea for this graph comes from a presentation by John Sargent, Senior Policy Analyst, Department of Commerce, at the CRA Computing Research Summit in 2004.

Student *vs.* Faculty Growth

- Since 2008, the number of CS majors has skyrocketed
- Faculty numbers have not kept pace.



Source: CRA, *Generation CS,* February 2017

Observation #2

Although student reaction to the dot-com bust and offshoring were factors in the decline of the early 2000s, institutional actions to limit student enrollment played a major role in both of the earlier declines. Institutions take such actions when they cannot hire enough faculty to meet student demand.

The Role of Institutional Action

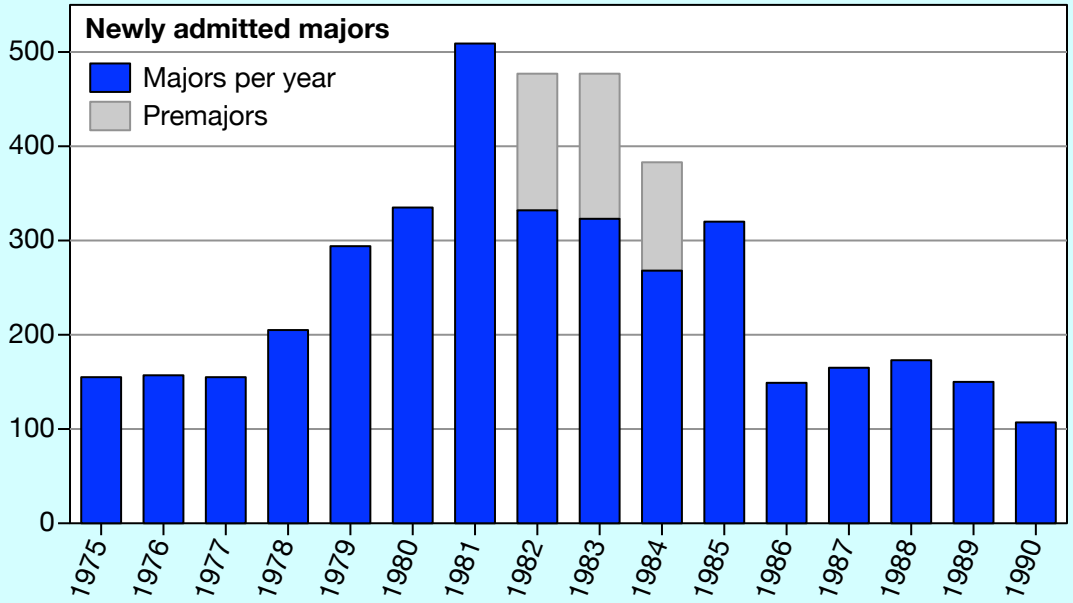
- Institutional actions taken in response to past enrollment surges have had a significant effect on degree production in computer science.
- Although it is difficult to obtain comprehensive data about institutional strategies that were put in place decades ago, it is possible to gain a sense of what happened by examining how individual institutions responded to the enrollment pressures.
- The evidence from individual institutions can be supplemented by looking at past studies by governmental agencies and the professional societies.

The Effects of Enrollment Limitation

- During past enrollment booms, many departments have sought to restrict demand by restricting admission to the major or by imposing enrollment limits on computer science courses.
- For the expansion in the early 1980s, the most comprehensive analysis comes from reports written at two universities that prepared extensive histories outlining the challenges of that time:
  - A history of the computer science department at Purdue, written by John Rice and Saul Rosen in 1990.
  - A historical analysis of computer science at the University of Maryland, written by Marvin Zelkowitz in 2007.
- The next two slides show how imposing admission restrictions affected the number of computer science majors at these two universities.

Enrollment Limitations at Purdue

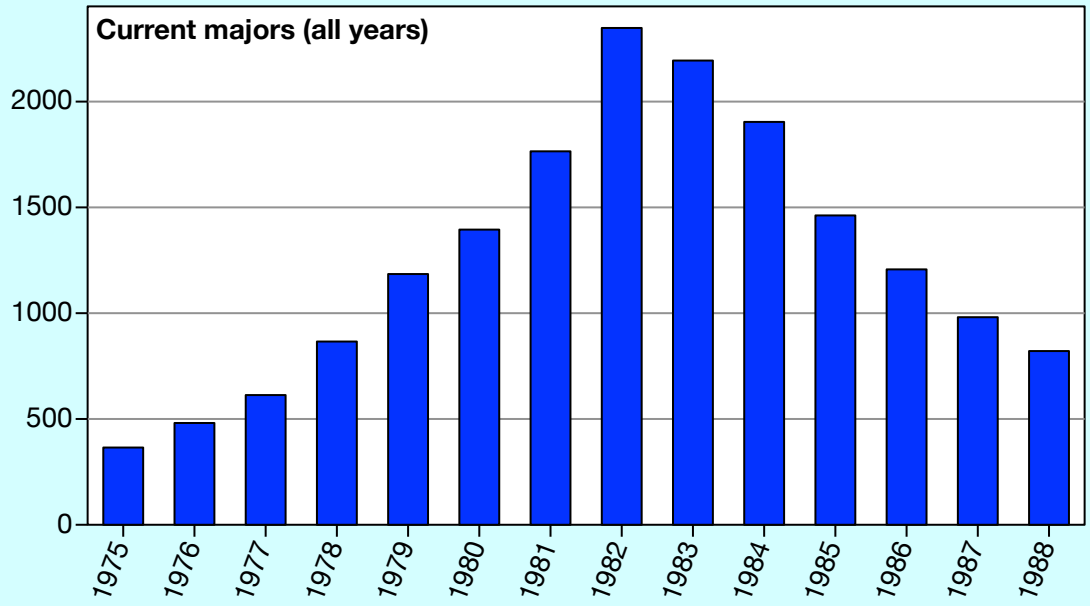
- Purdue restricted admission to its major in 1982, but students sought to circumvent the restrictions by becoming "premajors." The premajor category was eliminated in 1985.



Source: Rice and Rosen, "History of the Computer Sciences Department at Purdue University," 1990.

Enrollment Limitations at Maryland

- The University of Maryland enforced limitations on class size beginning in 1982 and restricted admission to its major in 1984, leading to a decline in majors over the next few years.



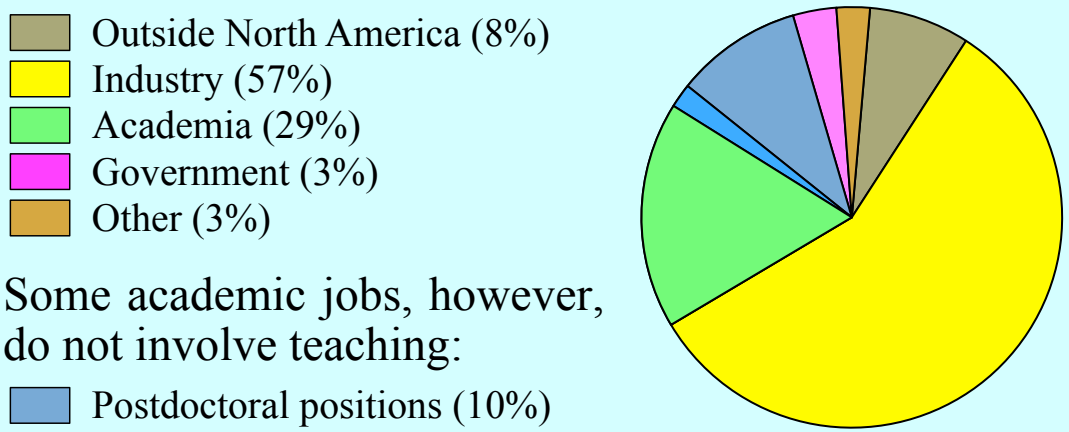
Source: Marvin Zelkowitz, "Maturation of Computer Science Research and Education at the University of Maryland," 2007.

Common Patterns

- The historical data from Purdue and Maryland show a common pattern in which imposing restrictions on the CS major lead to subsequent declines in the number of CS bachelor's degrees.
- Similar patterns exist at other universities. Rice and Rosen note that the crisis was in fact national and that "enrollments were ballooning wherever they were not strictly limited."
- Many universities chose to restrict the number of CS majors well below its existing level. UC Berkeley, for example, produced approximately 300 new CS graduates a year in the early 1980s. The imposition of departmental limits in the mid 1980s cut that back to around 100 graduates a year.
- Such restrictions inevitably reduce the number of CS degrees. They can also create unpleasant, competitive environments that eventually lead to lower student demand for the CS major.

The Supply of CS Faculty Is Tight

- The CRA Taulbee survey tracks where North American Ph.D. graduates take jobs. In 2015, the distribution looks like this:



- Some academic jobs, however, do not involve teaching:

- Even among those few Ph.D.s taking faculty positions, some will be gobbled up by a voracious industry.

The Shortage of Faculty Candidates

- According to the CRA Taulbee Survey, 1780 Ph.D. degrees in computer science were awarded in 2015.
- If only 18 percent of Ph.D. recipients take teaching positions in academia, that means there are only 320 new Ph.D.s available to fill faculty positions in the 1577 colleges and universities that offer CS Bachelor's degrees.
- On average, institutions can therefore expect to hire roughly 0.2 new Ph.D.s per year, or one Ph.D. every five years.
- Many institutions are looking for many more faculty to meet the expanding student demand. Northwestern University, for example, is seeking to hire 20 new computer science faculty. That number is 100 times the average institutional share.

The Situation Beyond the R1 Institutions

> *Wow, that is an excellent presentation, clear and concise in making a very important point. Being from an institution outside of R1 category, we are facing this challenge acutely.*
>
> —Professor Sathya Narayanan, CSU Monterey Bay

- The situation is much more difficult for schools outside the 115 universities that constitute the Carnegie R1 class of doctoral institutions with the highest research activity.
- Of last year's Ph.D. graduates taking faculty positions, 83 percent chose positions in R1 universities, leaving only 17 percent of the available candidates for the other 1462 colleges and universities that offer Bachelor's degrees.
- Given the current rate of Ph.D. production, institutions that fall outside the R1 category can reasonably expect to hire just one new Ph.D. every 27 years.

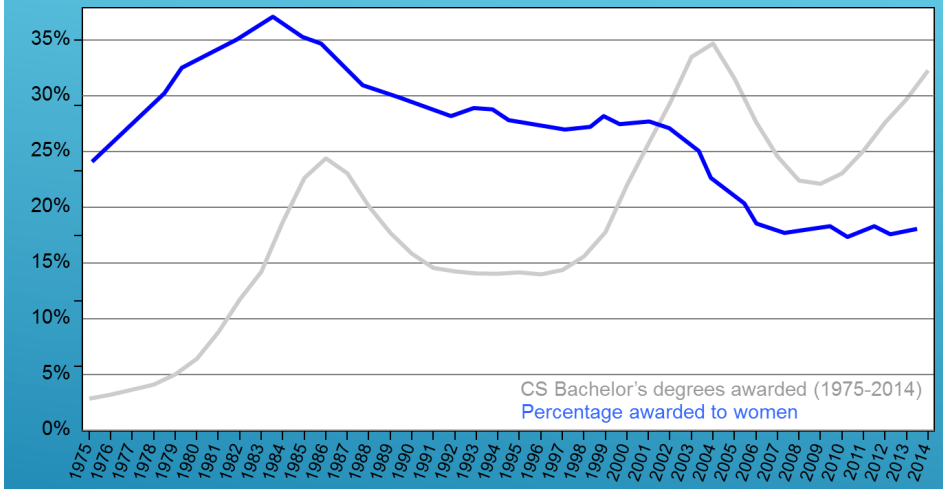
Observation #3

Beyond restricting the supply of workers for a vital sector of the economy, enrollment limitations have profoundly negative effects on student diversity.

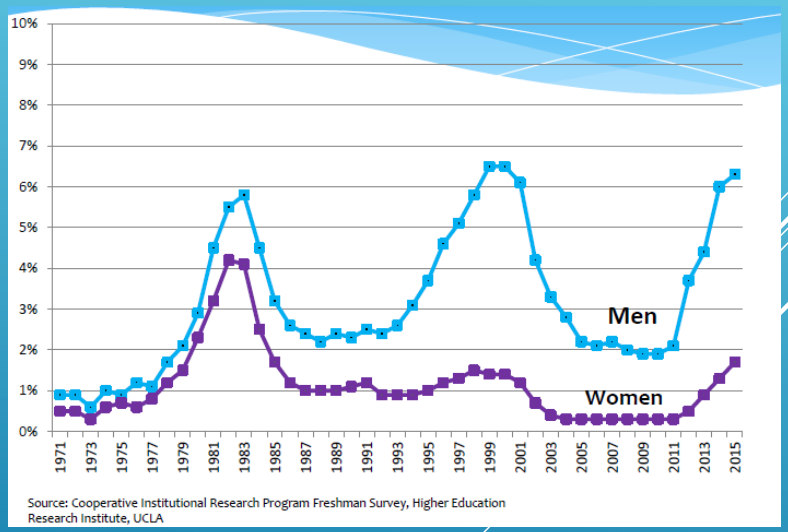
DIVERSITY IN TIMES OF BOOMING ENROLLMENTS

The opinions expressed are those of the presenter and do not necessarily reflect the consensus of the NAS study committee.

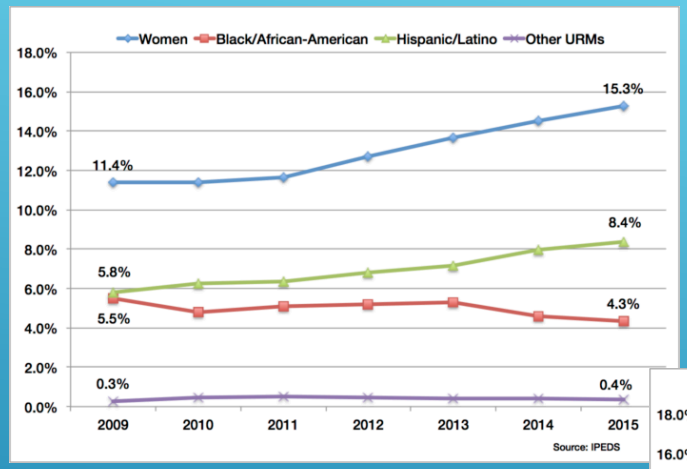
THE GRAPHIC REALITY - GENDER

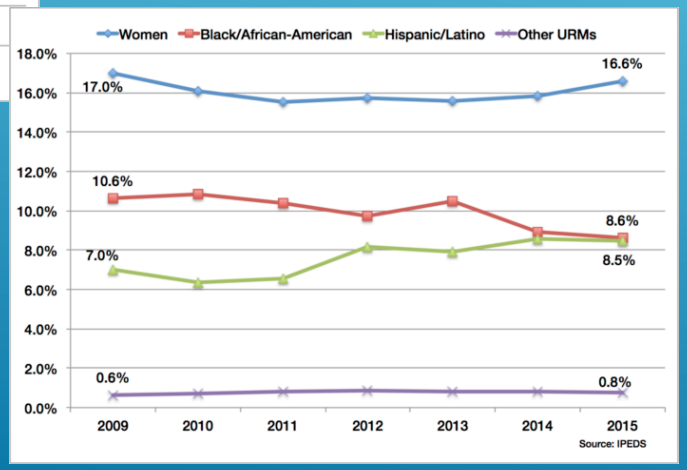


Source: National Center for Education Statistics, IPEDS database.



THE GRAPHIC REALITY - ETHNICITY





Graphics from *CRA Generation CS* report (2016) and reflect data at Doctoral (left) and Non-doctoral (right) institutions

Classification	US Resident Population*
American Indian/ Alaska Native	1.3%
Asian	5.7%
Black/ African American	13.3%
Hispanic/Latino	17.8%
Native Hawaiian/ Pacific Islander	0.2%
White, non-Hispanic	61.3%

*US Census Bureau estimates, July 2016

WHAT WE KNOW ABOUT IMPACTING DIVERSITY IN CS

- There is a wealth of information/research on best practices for recruiting and retaining diverse populations
  - Research matters – both performing/applying and including students
  - Resources matter - both to support programs/students and connecting students to them
  - Relationships matter – faculty, mentors, peer

HOW WILL SURGING ENROLLMENTS AFFECT DIVERSITY?

- It depends!
- Will institutions provide sufficient resources for best practices to continue?
- Will faculty have the bandwidth to continue participating in non-teaching/non-research programs to increase diversity?
- Will enrollment management practices factor in impact on diversity?
  - Admissions standards
  - Class size impacting pedagogical approach
  - Building strong, individual relationships with individual students?

Questions?