TESTIMONY OF DR. A. PAUL ALIVISATOS
Executive Vice Chancellor and Provost
and Vice Chancellor for Research
University of California, Berkeley

"STEM and Computer Science Education: Preparing the 21st Century Workforce,"
Wednesday, July 26, 2017
Research and Technology Subcommittee
House Committee on Science, Space, and Technology

Mr. Chairman and members of the Subcommittee, thank you for this opportunity to testify before you today.

My name is Paul Alivisatos, and I'm here on behalf of the University of California, Berkeley, where I have served as Vice Chancellor for Research, and just became Provost. I am also a professor of nanoscience and technology. I meet with my students most days of the week, and together we make discoveries, like the ones that form the basis of Quantum Dot TVs and tablet devices that are now widely available in stores. I previously directed the Lawrence Berkeley National Laboratory, which provides some of the most powerful scientific computing and data networking capabilities in the world available to tens of thousands of scientists from 17 national labs, hundreds of universities, and many companies large and small.

I've been invited to comment on the challenges and opportunities we are seeing in higher education for computer science and related fields. Tragically, even as computer science and technology and data science have permeated every aspect of our lives and the economy, the percentage of women and under-represented groups majoring in these disciplines has at best been holding steady and in many cases is actually declining. Further, the quantity of students we are able to train using current approaches is far too limited.

Today, I want to talk about the new approaches Berkeley is taking to better serve our community and nation in this area. **What can we do to increase the number and diversity of students who pursue computation and data sciences as well as other sciences and engineering subjects?**

First, our universities can create programs to try to address under-participation of women and minority students in Computer Science and related fields. At UC Berkeley, we have a number of programs that try to address this in different ways, which I discuss in my written remarks. One is the **CS Scholars Program**. The most recent cohort of 65 undergraduate scholars is the largest to date, with a representation of 62% female students and 26% under-represented minority students. Another is a **Computer Science Capacity Award** funded by Google that provides special discussion, tutoring and other support.

Second, at Berkeley we are opening up the power of data science to **all** students. Two years ago we established a course, Foundations of Data Science, that is based on helping students from any major or any background to address questions that interest *them*, using the powerful tools of data science. From linguistics to chemistry, and from history to economics, students from over sixty majors have responded, and this is the fastest growing program in the history of Berkeley; it will serve over a thousand students in the Fall. We are rapidly building on this success, adding follow-on classes, and we just hired our first Dean of Data Sciences. A new undergraduate major is in development, but even more important, a minor in data science will be offered and completed by **thousands** of students a year with an unprecedented range of diversity.

How can we build on this observation that students readily excel at technical subjects of great difficulty, even ones that they previously shied away from, when they are personally engaged in asking questions they care about? At Berkeley we are working to give every undergraduate the opportunity to engage in a hands-on discovery experience. It's amazing what happens to students' interest once you get them out of a lecture hall and into a research and discovery team. With greater inspiration and understanding of their field, we expect better student engagement and retention in their chosen majors, including Computer Science, to improve.
To offer personal discovery experiences to thousands more undergraduates, potentially even to all 27,000 who are at Berkeley at any one time, we will engage our talented graduate students and postdoctoral scholars as mentors. Discovery experiences hold promise to bring more talent to the hard problems our society faces, and to introduce a new generation of very well prepared students into vital sectors of our economy.

We are going to learn a lot from these initiatives, and I invite you to visit Berkeley to see how we are doing. I'd be happy to answer any questions you have. Thank you.

APPENDIX

The Evolving Landscape for Computer Science

Computation has become a critical aspect of almost every sector of the economy, not just a narrow segment, an essential part of almost every aspect of our daily lives, a critical component of essentially every field of inquiry, and a hallmark of our Nation's global leadership, and yet it remains largely an afterthought in our education system. Leading research universities began providing Computer Science degrees in the '60s. With the emergence of the Personal Computer in the '80s, along with electronic information processing in many industries, Computer Science programs spread across the higher education landscape, including 4-year Colleges, Liberal Arts institutions, 2-year Community Colleges, and For-profit institutions. Today roughly 1,500 institutions offer Bachelor degrees, over 500 offer Masters, and nearly 200 offer PhDs - largely in reaction to rapidly growing student demand. In the last few years, we have begun to introduce Computer Science concepts in the K-12 education pipeline.

Indications of the sweeping change of the role of computing and information technology in our society are everywhere, we note a few here:

- In this year, we will cross the threshold where the majority (50%) of the world's population use the Internet, from less than half a percent in 1995. [http://www.internetworldstats.com/emarketing.htm#stats].
- Today, nearly two billion people are active Facebook users, over 1.5 Billion Google searches will performed, and over 1.7 Billion videos will be viewed on the Internet.
- Of the five companies with the largest market capitalization, in 2016 all of them are Information Technology (Apple, Alphabet, Microsoft, Amazon, Facebook), whereas until even five years ago, this was dominated by Energy and Financial companies (in 2011 Exxon, Apple, PetroChina, Shell, Industrial and Commercial Bank of China) [http://www.visualcapitalist.com/chart-largest-companies-market-cap-15-years/]
- From 1978 to 2015, the number of people working in computing occupations rose from 219,000 to 4,106,000, an increase of nearly 1800% over a period in which total employment rose by only 58%. [Source: Bureau of Labor Statistics, Current Population Survey]. Particularly because most jobs in computing require at least some university-level education, the dramatic increase in employment has had a significant effect on the number of students seeking computing degrees.
- As of 2014, the number of people employed in computing occupations was 3,916,100.[1]The total number of Bachelor's degrees in computer science awarded by U.S. institutions *throughout the entire history of the field* is only 1,313,034.[2] The number of employees in computing occupations is therefore approximately three times larger than the number of Bachelor's degrees in computer science ever produced in the United States. [Bureau of Labor Statistics. 2015. *Employment Projections: 2014-2024.* Washington, DC: Bureau of Labor Statistics, December 2015, Table

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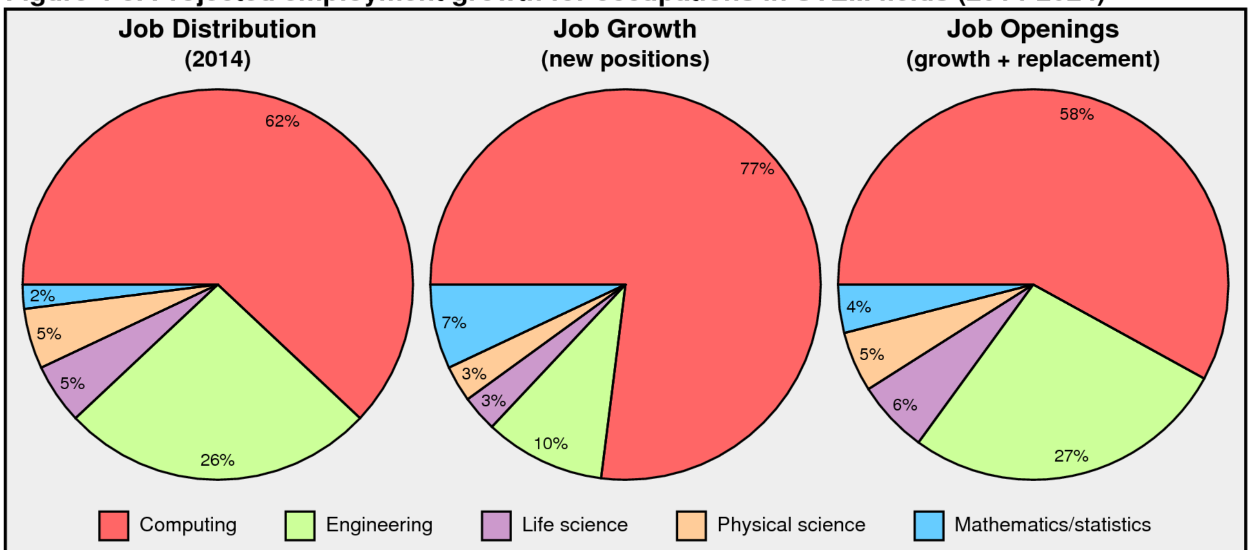
[1] Bureau of Labor Statistics. 2015. *Employment Projections: 2014-2024.* Washington, DC: Bureau of Labor Statistics, December 2015, Table 11b.
http://www.bls.gov/cps/cpsaat11b.htm

[2] National Center for Education Statistics. 2016. Integrated Postsecondary Education Data System (IPEDS).
http://ncsesdata.nsf.gov/webcaspar/

11b.] [http://www.bls.gov/cps/cpsaat11b.htm] [National Center for Education Statistics. 2016. Integrated Postsecondary Education Data System (IPEDS). http://ncsesdata.nsf.gov/webcaspar/]

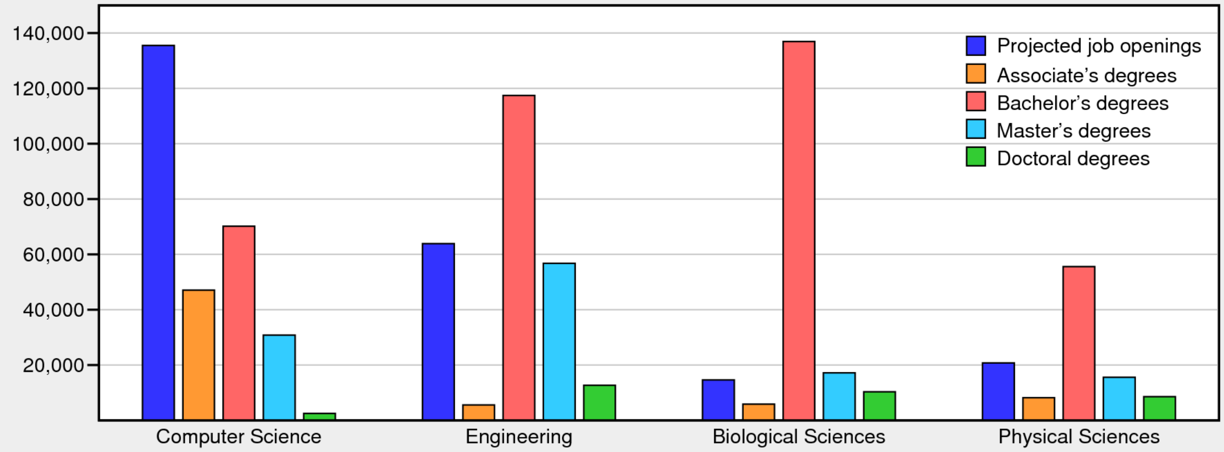
- Over the past 20 years the number of computing occupations has grown at an average rate of 143 thousand jobs per year, while computer science BA production has increased from about 20 thousand to just over 60 thousand. While this growth has placed tremendous demand in educational institutions, it still has not kept up with the demands of the economy.
- [In 2015] there were more than 600,000 high-paying tech jobs across the United States that were unfilled, and by 2018, 51 percent of all STEM jobs are projected to be in computer science-related fields. Computer science and data science are not only important for the tech sector, but for so many industries, including transportation, healthcare, education, and financial services. [Megan Smith. 2016. Computer Science for All. Washington, DC: Executive Office of the President, January 30, 2016. http://www.whitehouse.gov/blog/2016/01/30/computer-science-all/ (retrieved December 17, 2016)]
- BLS projections for 2014-2024 predict that 77 percent of all new STEM jobs will be computing related.

Figure 4-3. Projected employment growth for occupations in STEM fields (2014-2024)



Source: Bureau of Labor Statistics, Employment Projections: 2014-24

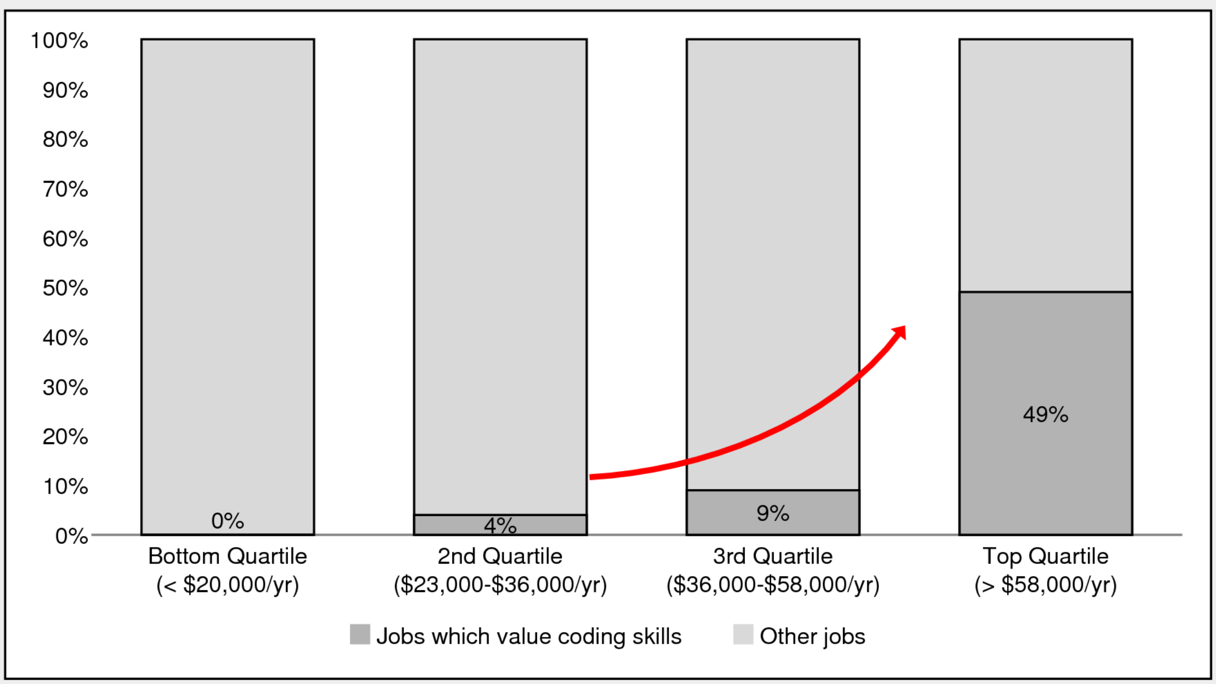
Figure 4-10. Projected annual job openings and current degree production in broad STEM fields



Sources: Anticipated annual job openings from Bureau of Labor Statistics Projections 2014-2024.
Degree data for 2014 from National Center for Education Statistics, Integrated Postsecondary Education Data System (IPEDS).

With these trends, the availability of CS education has a profound impact in shaping participation in economic prosperity. Burning Glass estimates that 49% of the jobs today in the top quartile of earnings value coding skills. Segments of society who are not provided with these skills in the course of their education are largely relegated to lower paying careers.

Figure 4-4. Percentage of job openings that value coding skills, by income level



Source: Burning Glass Technologies, "Beyond Point and Click: The Expanding Demand for Coding Skills," June 2016.

Demand and Capacity Challenges at UC Berkeley and Other Universities

The growth in production of CS degrees, while rising dramatically over the past 35 years, has also gone through fluctuations around that trend. Immense growth was experienced in the mid ’80s following the emergence of Personal Computers. Another wave of huge growth was experienced during the late ’90s through early 2000s with the emergence of the Web. A third wave has been experienced from 2008 and continuing, with the emergence of the smartphone and digitization of almost every aspect of daily life.

Many efforts have attempted to ascribe the fall-off of student demand from the peaks to reduction in demand for CS workers in broader economy, often using models of the lag due to the education pipeline to explain the asserted “over production.”

Such explanations appear to bear little connection to evidence, as in only 3 of the last 20 years has there been any reduction computing related jobs (2001-2002 with the Internet bubble and during the great recession when occupations as a whole were reduced) and the variations in job growth bear no correlation with variations is BA degree production, even after accounting for the lag between decision to major and graduation. Today there are 80 computing jobs in the economy for every CS BA produced.

A simpler explanation of the reductions in CS degree production is simply the restrictions placed on enrollment into CS-related courses and admission into CS-related majors by Universities in order to cope with the excess demand placed on its limited resources—faculty, staff, facilities, and graduate student teaching assistants.

Application of measures to address large demand growth can easily result in a loss of student interest. Highly selective admission to courses and programs of study typically results in a highly-competitive atmosphere, placing stress on students, faculty, and staff, and may discourage segments of the student population--and thereby of the future workforce--who feel underrepresented or otherwise marginalized. Enlarged courses can result in a loss of quality and individualized treatment. Utilization of instructors untrained in the field to expand teaching capacity and thereby maintain class size can reduce quality and enthusiasm. The collective result can be a drop in production and demographic diversity.

UC Berkeley, like most universities and colleges, instituted such measures and experienced such effects. In the early ’80s, when experiencing huge growth in demand for courses when instructional facilities were limited by the number of available mainframe terminals, we progressively instituted restrictions - first limiting enrollment in entry courses, then upper level courses, then set an elevated grade point average for admission to the major, and then a hard limit of a 100 students per cohort. With a GPA cut-off of 3.0 into the Letters & Science CS major, the size cap resulted in an effective cut-off about 3.8 to 3.9. And the size of the graduating class was reduced over three-fold, despite the state and nation’s workforce needs. Eventually, the major lost popularity, despite continued job growth.

During the run-up to Y2K, when experiencing a similar surge to an even larger peak, we phased in restrictions far more carefully. Program scale was limited not so much by underlying facilities, given the introduction of personal computers and workstations in the instructional labs, but rather by the workload placed on the faculty, staff, and graduate student researchers. The modest reduction in workforce demand in 2001-2002 and increase in national PhD production (which enabled faculty growth) permitted a more graceful transition to new production levels. These measures were in place as dramatic growth resumed in 2008.

Understanding this problem and the measures to address it requires understanding the academic institutional production landscape in finer detail than the overall national picture. Of the 1576 CS Bachelor degree granting institutions in the US in 2015, 100 schools (6%) produce over half of the graduates. A small number of schools, largely Research Universities, have very large programs, while a very large number of schools have quite small programs.

Not only are institutions quite heterogeneous, the growth in demand they are experiencing varies widely. While overall growth in production since 2009 is 1.5x, six hundred of these have more than doubled, three hundred have more than quadrupled, and some have increased over 10-fold. Meanwhile, programs at 400 institutions have shrunk, despite overall growth. Consolidation into large, successful programs is occurring.

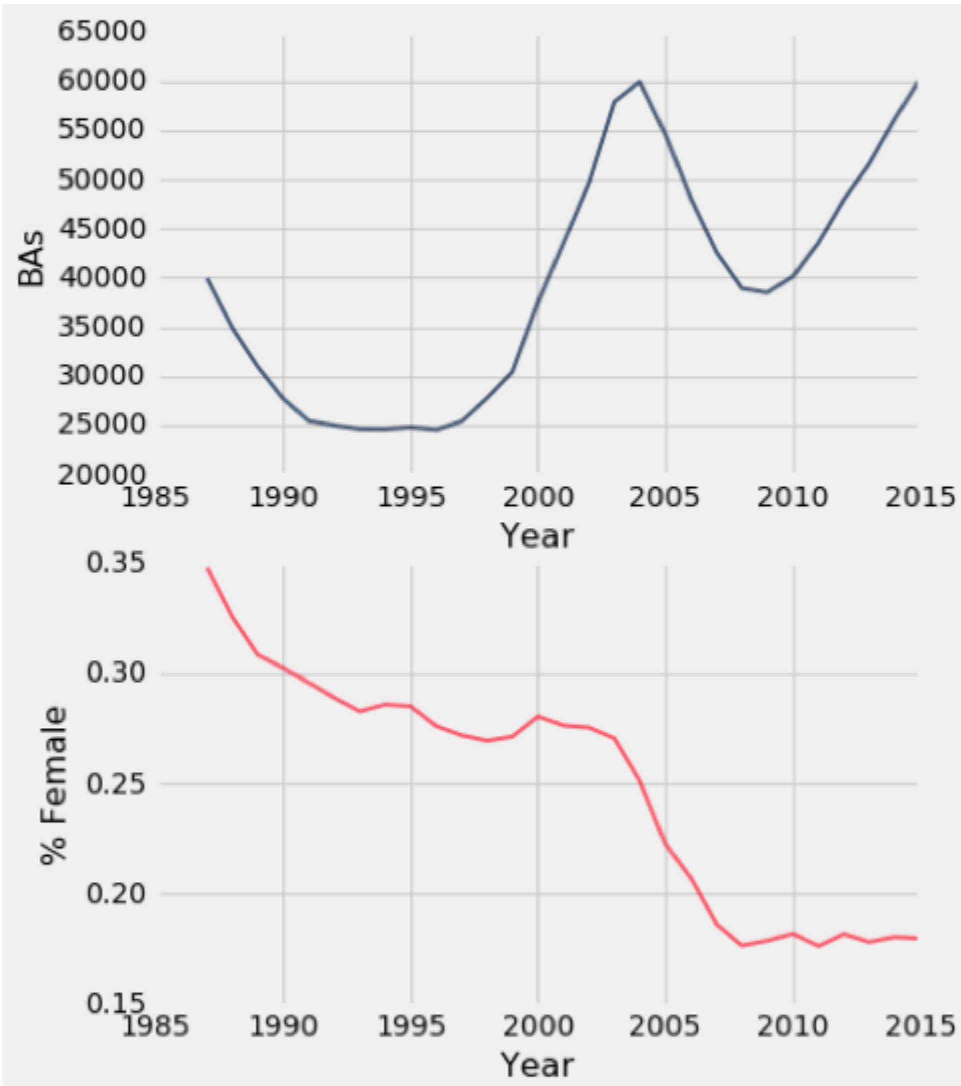
The underlying question here is the size of the faculty relative to the size of the student body. According to Computing Research Association Taulbee Survey data, the number of computer science majors at the universities in the Taulbee survey increased by 241% from 2006 to 2015, while tenure-line faculty at those same institutions has grown by just 23%. Some of this gap is addressed by an increase in teaching faculty, which grew by 68%.

However, even if institutions are prepared to grow the faculty, given limited PhD production and strong industry demand, few will be able to do so. In 2015, 1999 Computer Science PhDs were produced nationally [IPEDS]. According to Taulbee surveys, 57% go to Industry and 3% to Government. Only 10% (200) go into Academic Tenure Track jobs and 5% (100) to Academic Teaching positions. The bulk of these go into the large Research Universities. Most smaller institutions can expect to hire a new CS faculty member only once every several years, so growth in capacity is very slow. And, for the research institutions that can grow, with NSF budgets essentially flat and NSF providing 82% of basic research support for Computer Science [https://www.nsf.gov/news/speeches/cordova/17/fc170327_aaaspolicyforum.jsp] (higher than any other area), it will be hard for to maintain healthy research programs.

Thus, acute pressure to operate Computer Science programs under excessive student demand, while sustaining active research programs, and in the presence of tremendous commercial opportunity outside the University, will persist into the foreseeable future. And issues of diversity and representation will need to be addressed in the context of these pressures.

Participation of Women in Computer Science

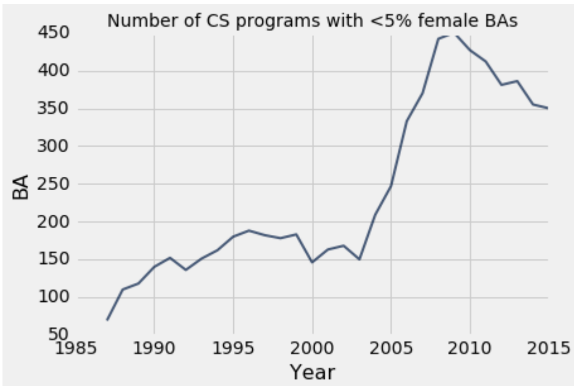
A strong indicator of the impacts on student climate of institutional response to periods of huge demand growth for computer science education is the participation of women in these programs. Prior to the onset of mechanism to address growth in demand in about 1983 women comprised over 35% of the Computer Science student body nationally. By 1990, after mechanisms to restrict access and to grow capacity through bringing in instructors from outside the field, participation of women dropped below 27% and never recovered. Following the onset of measures to address the Y2K growth surge, during which the many younger programs facing the first such experience instituted measures similar to those of older ones during the ’80s, participation fell further to about 17%.



While economic theory would suggests that women and men would be drawn into the field by employment opportunities and corresponding earning differentials relative to other majors, persistent gender imbalance in student production inevitably leads to disparity of representation in the workforce, which is likely to dissuade the underrepresented group from pursuing programs of study leading to to such jobs.

One conclusion is that, in order to remedy the imbalance present in a workforce that is literally serving the people of the entire planet in almost every aspect of their life, large, leading universities must take internal measures to maintain interest in computing related programs across the spectrum of the student population while they are taking measures to address huge student demand.

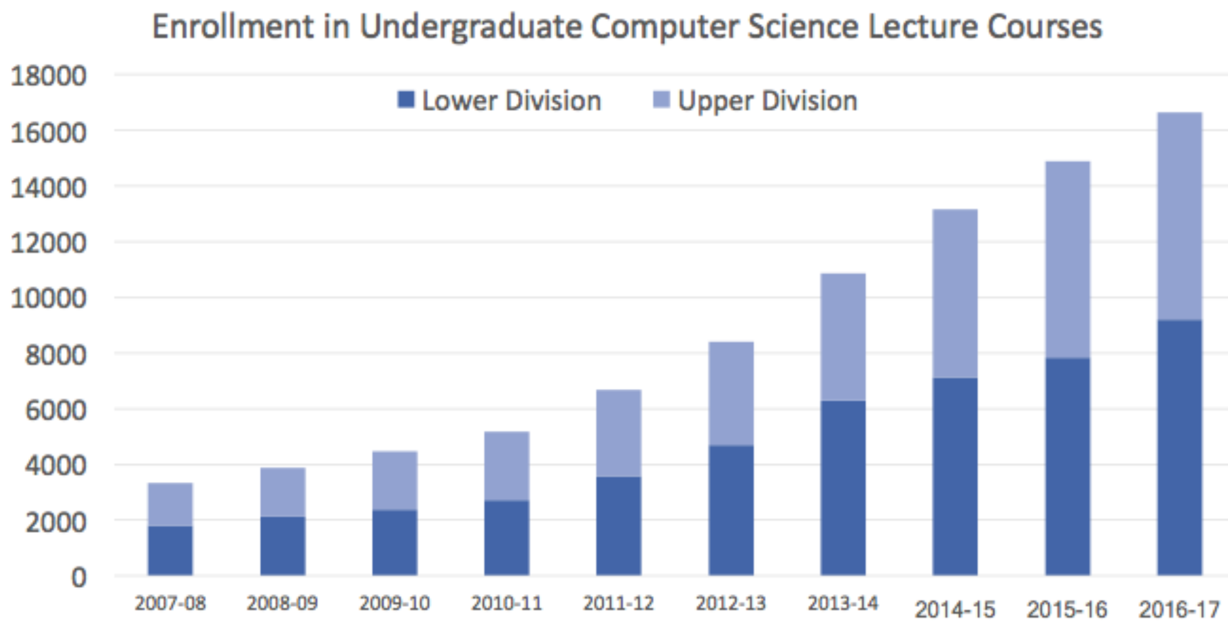
However, the large number of small programs raise a very poignant concern. In 2015, 800 of the programs had less than three women in the graduating class; 350 have less than 5% women. These observations are particularly concerning because most successful remedies rely upon building a critical mass cohort that can provide a supportive environment for the underrepresented segment.



UC Berkeley Programs to Address These Issues

UC Berkeley began to experience a rapid growth in student demand after 2006. During the recession, growth was as rapid as leading into the Internet boom. Starting in 2010 the EECS department became concerned again about the growth in enrollments and in majors. Faculty preferred taking on larger enrollments to dealing with frustrated and forlorn students. Having gained experience with the effect of previous growth waves, we began a series of measures to handle the demand while preserving climate in a manner that would restore, rather than further diminish the demographic diversity in the program. A shift had already been made toward utilizing undergraduate TAs in the lower division. This involved a fairly sophisticated development pipeline where students who performed well in a course could be employed as graders and then lab assistants, and if they did that very well they could become TAs. A culture of students teaching students developed that included substantial technical development on course technology as well as tutoring and teaching. An additional teaching professor was added. A range of novel teaching practices and several initiatives that were designed to encourage broader participation in computer science and improve the academic performance of students with limited prior programming experience.

Total course enrollments for undergraduate CS lecture courses was five times larger (+398%) in 2016 than 2007.



Placing the growth of majors in the larger context, the graduating class in 2016 was far larger than the previous peak of the Internet boom. Growth in the EECS major, in Engineering, was constrained by selective admission into the University and the requirements for declaration of Letters & Science CS major as a junior was set to match the performance of EECS students at the same stage, without an a priori cap. With these measures in place, the EECS BA production grew 1.4x compared to 2009, while the L&S CS production grew 5.3x. Importantly, production in Applied Math grew 1.8x and in Statistics 4.2x in this timeframe.

In 2009, UC Berkeley's Computer Science Department began piloting a 2-unit course called "**The Beauty and Joy of Computing**" to 20 non-major students, based on work supported by NSF. It was such a success that we decided to make this course a full 4-unit introductory course in Computer Science concepts for students who do not see themselves as interested in the major. It has grown to enroll over 500 students per year (in the two regular semesters and summer) and about a third change their direction and go on to take the introductory course for majors, CS61A. Its curriculum has been an important contribution to the NSF CS10K program throughout the nation and contributed to the new AP CS Principles exam. In the spring of 2017, **60% of its students were female,** shattering the gender diversity record at UC Berkeley for an introductory computing course. The team has been incredibly active to share the course more broadly; by the end of the summer, they will have offered professional development to over 300 high school teachers across the country. Links to more information:

- http://bjc.berkeley.edu
- http://engineering.berkeley.edu/2009/12/oh-beauty-and-joy-computing
- https://www.nytimes.com/2017/04/04/education/edlife/teaching-students-computer-code.html
- http://cs10.org/sp17/

It was not until 2011 when Code.org got its start, that this original concept was expanded more broadly. Now, this non-profit has grown with national and international recognition, and several other successful programs have replicated this model in the US with a similar mission.

At UC Berkeley, we have a number of other programs that try to address under-participation of women and minority students in Computer Science and related fields, including:

- **CS KickStart** [https://cs-kickstart.berkeley.edu] is a week-long program open to any incoming UC Berkeley students and introduces them computer science while meeting other computer science students and professionals. This program primarily targets women who are interested in the fields of science, technology, engineering, and math. Participants get hands-on experience in programming introducing them to the creativity and diversity of computer science. Participants also get the opportunity to visit tech companies in the Bay Area to see what life is like for computer scientists in industry. For several years it served 25 incoming students, but recently this doubled. It draws almost all of its support from industry and individual donors.

- T**he CS Scholars Program** [https://eecs.berkeley.edu/cs-scholars] began in 2009 at UC Berkeley and has created a community in which students can learn and grow together. The EECS Center for Student Affairs (CSA) recognizes the unique challenges that students from under-resourced and low opportunity communities face at the university and in computer science, and therefore our goal is to provide a supportive network in which students can thrive. Now in its eighth cohort, the CS Scholars Program supports 350 scholars through a three uniquely designed courses. The spring 2017 cohort of sixty-five scholars is the largest cohort to date, with a representation of 62% female-identified students and 26% under-represented minority (URM) students.

- **Computer Science Education Day** [https://eecs.berkeley.edu/csedday] at UC Berkeley aims to inspire and motivate High School students to learn more about computer science, the opportunities it affords them, and exciting research and educational activities occurring on the UC Berkeley campus. Although it is only one day, it mobilizes STEM students at UCB to engage with and directly inspire high school students and has proven to have lasting impacts.

- **Summer Undergraduate Program in Engineering Research (SUPERB)** [https://www2.eecs.berkeley.edu/Diversity/SUPERB/reu.shtml] is an NSF-funded Research Experience for Undergraduates (REU) program at UCB, with a goal of preparing and motivating a group of diverse, competitive candidates for graduate study. The research focus of the REU will be collecting and using Big Data for the public good. SUPERB-Information Technology of Sustainability (ITS) participants spend nine weeks at UC Berkeley during the summer working on exciting ongoing research projects in information technology with EECS faculty mentors and graduate students. Students who participate in this research apprenticeship explore options for graduate study, gain exposure to a large research-oriented department, and are motivated to pursue graduate study. SUPERB-ITS participants receive a stipend, room and board on campus in the International House, and up to $600 for travel. 95% of the students who have participated in this program have gone on to graduate school in the STEM fields.

- **Girls In Engineering** [http://girlsinengineering.berkeley.edu/sponsors.html] is designed to grow the next generation of engineering leaders through an experience built on hallmarks of Berkeley Engineering: hands-on, team-based learning; an emphasis on leadership; and engineering in a societal context. In our College of Engineering, 24% of our engineering undergraduates are women, which is better than the national average. Encouraging diversity among students and faculty in engineering is a top strategic priority. Supported by an initial grant from NSF, the Girls in Engineering program is a week-long, non-residential summer camp for San Francisco Bay Area girls entering 6th, 7th, and 8th grades to explore different aspects of what it means to be an engineer in a fun, hands-on environment. Girls learn leadership skills such as goal setting and effective communication, and engage in activities that showcase different engineering disciplines.

Participants will also design and create engineering projects throughout the week under the guidance of Berkeley faculty, staff, and students.

- **Scaling Computer Science through Targeted Engagement** [https://research.googleblog.com/2017/02/the-cs-capacity-program-new-tools-and.html] is focused on providing access to increased and better tutoring, including weekend mastery learning sessions, increased office hours support, designated discussions section, project checkpoint deadlines, and a new office hours app that tracks student satisfaction with office hours. Google supported this program in 2015 as one of its Computer Science Capacity Awards, which address issues arising from the dramatic increase in undergraduate CS enrollments. The effect of these measures is very encouraging. The number of female L&S CS graduates grew 12-fold from 2009 to 2016, with the participation of women has grown steadily from under 12% in 2009 to over 28% in 2016, all while expanding a highly selective program.

A Broader Focus on Data Science Across Campus

Beyond computer science, at Berkeley we saw similar dynamics emerging more than half a decade ago in the new field of data science. Data science combines high-powered computing with advanced statistics to analyze massive data that push forward new industries and new scientific frontiers, from human health to galaxies, from biological systems to social behavior. At a very early stage, it was already clear that data science would go beyond revolutionizing computer science and computer technology. This impact was rightly foreseen in the Presidential Big Data Initiative of 2012. Inside UC Berkeley, our faculty saw that data science would fundamentally reshape teaching and research across many fields. When we decided in 2014 to embark on creating an undergraduate data science curriculum, we approached it from the ground up. As we saw it, this was a moment to rethink at a fundamental level what every educated person must know about quantitative reasoning: how to effectively understand, process and interpret information, to inform decisions in their professional and personal lives and as citizens of the world in the 21st century. We aimed to build our data science classes from Day 1 in a way that would be accessible and inviting to all students, beginning with a new course that a team of our leading faculty designed from scratch to define the Foundations of Data Science.

Berkeley's Data Science curriculum was launched at the entry level in fall 2015 with this innovative course, which has grown in two years to serve well more than a thousand students a year. It is the fastest-growing class in UC Berkeley's history, and it is designed to be engaging and accessible to any student who gains entry to the university, without any additional background or experience. It teaches fundamental concepts of inference and computational thinking through hands-on computing on data in Python, and picks real-world examples like jury selection, water use in California, or global population health. Starting from these examples, as well as discussions of privacy and impact, the social and ethical implications of data science are consciously addressed. Running alongside the Foundations class are a suite of so-called "connector courses" that relate the material directly to students' own areas of study. The "connectors" have seen a groundswell of student interest as well, and now range from neuroscience to civil engineering to criminal justice to history. This set of entry-level courses is designed to provide the base for later classes in a broad range of departments that will be able to leverage and extend what students have learned. The upper tiers of the program are now being developed and will provide additional depth and connect across the campus with major and integrated minor offerings.

Because of how Berkeley designed the overall program, the Foundations of Data Science class has been diverse from the start. It is accessible with basic mathematics and no previous programming experience, at the same time as it is conceptually strong. The third semester it was offered, it was just over 50% female (nearly matching the university as a whole), with a significant population of underrepresented minorities. The broad reach of the class creates a diverse pipeline of students who continue onward feeling confident that their perspectives are integral to data science. The Foundations class has drawn in students from more than 60 majors so far, from computer science, math, and statistics to the social sciences, biology, and public health.

A key aspect of the program has been creating a state-of-the-art cloud-based data science stack for education that lets students easily jump into computing with a minimum of barriers. During the class, students can write and edit code in a browser in real time, working on a laptop with the same data set and code that the professor is discussing. Learning in the class is active, and interactive: In so-called Jupyter Notebooks, students can try their own calculations, using large data sets that are available at their fingertips, and follow up with questions to the professor. All of these innovations are driven first and foremost by the goal of reducing the barriers to computing instruction, in order to broaden participation at the base, where it matters so much.

Berkeley's data science program is actively welcoming to students of many backgrounds and interests. There is a Data Scholars program on the CS Scholars model to support underrepresented, first-generation, and non-traditional students, as well a student outreach team that explains the program to other students in their own language. Another team of students and staff helps professors across the university introduce data science modules into their own classes, where students can encounter it and be drawn into the field by experiencing the power and insight of computing on data.

The tremendous workforce demand for data science and analytics has been broadly understood. In our wired, connected, and data-saturated world, data fluency will soon be essential in *many* careers. As documented in the April 2017 report "Investing in America's Data Science and Analytics Talent" (Business-Higher Education Forum and PwC), market analyses call out 2.7 million job postings for strongly data-enabled roles by 2020, and the demand is growing across industries. Leading universities such as Berkeley not only need to prepare their own graduates for this world, they have an obligation to change the national landscape. As the new field of data science grows in its impact and pervasiveness, it must be shaped by a diverse population of practitioners at the national scale.

More information: http://data.berkeley.edu/

In recognition of the transformative potential of data science—its pervasiveness, significance, and continuing evolution—a data science initiative has already been having noticeable effect on campus. The data science initiative is led by faculty and aligned with regular Academic Senate processes and campus-level strategic planning. It aims to advance Berkeley's excellence in fields around data and computing and to connect them fluidly across the campus. The initiative creates pathways for the university to move flexibly and decisively into new domains. It is charged to recommend opportunities and strategies for research, teaching, organization, and fundraising. The reach of Berkeley's new data science education program serves as a model.

The initiative builds upon our outstanding research and graduate programs and our pathbreaking undergraduate curriculum. It draws together our wide-ranging excellence by engaging our community in its formative stages, and it integrates our intention to advance the university's public mission by engaging with the societal, humanistic, and policy ramifications of data science. The initiative is defining pathways of institutional development that can fit the world's leading public university for the 21st-century world. Starting July 1, 2017, Berkeley took a major step in appointing an Interim Dean of Data Sciences to build out a program at the same level as the Colleges and Schools in our academic structure.

Undergraduate Discovery Experiences

We have seen that students readily excel at technical subjects of great difficulty, even ones that they previously shied away from, when they are personally engaged in asking questions they care about. At Berkeley we are building on this observation in an initiative that would give every undergraduate the opportunity to engage in a hands-on discovery experience. It's amazing what happens to students' interest once you get them out of a lecture hall and into a research and discovery team. With greater inspiration and understanding of the field, we expect better student engagement and retention in their chosen majors, including Computer Science, to improve.

The Berkeley Undergraduate Discovery Experience is a campus-wide initiative to engage and support more undergraduate students in scholarly and experiential learning. Developing the capacity to inquire, discover, and create is the core purpose of an undergraduate education. It's amazing what happens to student's interest once you get them out of a lecture hall and into a research team.

The broad term "Discovery Experience" references a wide range of immersive learning projects--from substantial research experiences and artistic production to entrepreneurial initiatives and community-engaged projects. All such efforts should challenge students to question, design, implement, and iterate toward a thoughtful and creative culminating product. Many of our undergraduates already partake in such experiences. We aspire for all of them to do so.

Our intent is to create a campus-wide platform through which undergraduate creativity can be channeled, challenged, supported, and expressed. The Discovery Experience has the potential to become the defining experience of a Berkeley undergraduate education, where the popular question "What is your major?" will be complemented by "What is your discovery project?"

Some students will pursue the path of a traditional senior thesis, while others might seek the challenge of writing a novellae, directing a film, launching an entrepreneurial endeavor, or integrating community engagement with scholarship. Some experiences will be group-based while others individual. While new requirements might emerge at the departmental level, it's important to consider how some students will reach this goal outside of the major: e.g., in a minor or perhaps through a co-curricular experience. In the broadest sense, the challenge for the campus is to build upon existing programming and launch new programming that expands pathways through which students can foster their passions and complete a discovery project.

To offer personal discovery experiences to thousands more undergraduates, potentially even to all 27,000 who are at Berkeley at any one time, we will engage our talented graduate students and postdoctoral scholars as mentors. Discovery experiences hold promise to bring more talent to the hard problems our society faces, and to introduce a new generation of very well prepared students into vital sectors of our economy.