

Enrollment Management Proposal for the Computer Science Department

Executive Summary

In the last six years the number of Computer Science majors (proposed plus declared) has increased from 238 to 2178, and the number of CS declared majors has increased from 143 to 1033 . At this time the Computer Science BS major is the second largest major on campus, just behind Psychology, and it is posed to become the largest one next year. In addition to growing interest from freshmen, the department also admits a large and increasing number of transfer students (~175 last year alone), making an important contribution to the campus goal of reaching a 2:1 frosh-to-transfer admission ratio. The CS department also has one the largest graduate programs on campus with 104 PhD students and 85 MS students. On the flip side, in the same six-year period, the number of CS Senate faculty has decreased from 24 to 22; of the 22, two are in administrative service outside the department (VCR and Dean). In 2016-17, the campus average instructional workload ratio was approximately 29 undergraduate student FTEs to permanently budgeted faculty FTEs; the corresponding number for CS was 56, an increase of 30% over the previous year; considering only the 20 faculty serving in the department, the ratio reaches 61. Compared to other CS departments in North America, our CS department has a 100:1 majors to faculty ratio and a 50:1 declared majors to faculty ratio for 2016-17; this is **twice** the level of the 90% percentile of other CS departments; the overload is so severe that the department is literally in uncharted territory in terms of how under-served the students are.

Until this point, the CS department has tried to support the surge in enrollments without the use of enrollment management. The measures taken, detailed in the appendix, included precipitously increasing class sizes, hiring more lecturers, requesting augmented teaching resources ranging from temporary FTEs to teaching assistants and graders, and streamlining the curriculum in ways that have been fairly draconian. The curriculum of many classes that were designed for 100 or fewer students has been redesigned to accommodate 300 at a time. As the surge in Computer Science interest has accelerated, however, these measures are falling far short. It is becoming increasingly difficult for CS majors to enroll in the classes that they need to graduate in time, to the point that in some quarters several students have been unable to enroll in *any* classes needed for their CS major and are considering dropping out, or taking periods of leave. Furthermore, at this time it is not only possible but likely for students to graduate with a CS degree without ever having taken a course from a Senate faculty in the department. This trend will only get worse as the imbalance between CS student population and CS faculty grows, impacting graduation rates, student satisfaction, education quality, and faculty retention. The trend also affects the ability of the department to maintain, let alone grow, its graduate programs. This is in spite of the high demand at both the MS and PhD levels and the availability of extramural funding to support additional students.

This proposal lays out our approach to enrollment management. **Our short term goal is to stem further growth of the major and slightly bring down the number to frosh students that eventually declare CS majors to the levels of two years ago, while increasing**

graduation rates, reducing time to degree, minimizing the impact on diversity and ensuring enough capacity in our course so that we can accept all qualified transfer students that are interested in our programs. A side benefit of these slightly lower targets is that it will allow us to modestly expand the number of students in our graduate program. **Our medium term goal is to improve our student/faculty ratios and expand access to the major to additional frosh,** but this will require a commitment from the campus to increase the number of Senate faculty in the department. A summary of our specific requests follows:

Applications:

- Require applicants interested in CS to declare CS as proposed major at the time of application to UCSC, and clearly advise them that failing to declare it as their intended major will result in them not being able to pursue a CS major. We understand that the campus has included in the UCSC application and admissions documents, literature, and web pages a statement to the effect that the choice of major may be taken into account in the admission process for UCSC.

Admissions:

- Limit to 475 the number of CS-proposed BS and BA frosh that enter the campus for the 2018-19 year. Admission targets for future years will be developed jointly by the school of engineering and the admissions office. While we defer to the admissions office for the implementation, we suggest in the document criteria that can be used for such selection. Our suggested criteria aim at weeding out students that have low probability of declaring a CS major in time and mitigate the effect of the proposal on diversity.
- No restrictions are being proposed for transfer students. We have about 175 transfers a year in CS. We expect the restriction to 475 proposed CS frosh admissions per year will lead to about 350 CS BS declarations per year, leading to a 2:1 ratio between yearly CS BS declarations and CS transfers.

Major migration:

- Only students who applied to UCSC for a CS major can declare a CS major.

In the remainder of the impaction request, we detail the need for these measures, and we justify the particular numerical limits proposed. Because of how interrelated the different BSOE majors are, we expect that the School will be submitting a broader enrollment management proposal encompassing other growing majors in engineering that will complement this one. However, we believe that the situation in Computer Science is too dire for us to wait for a BSOE-wide proposal. Swift action is required for the CS BS degree to remain viable.

The Growth in the CS Student Body

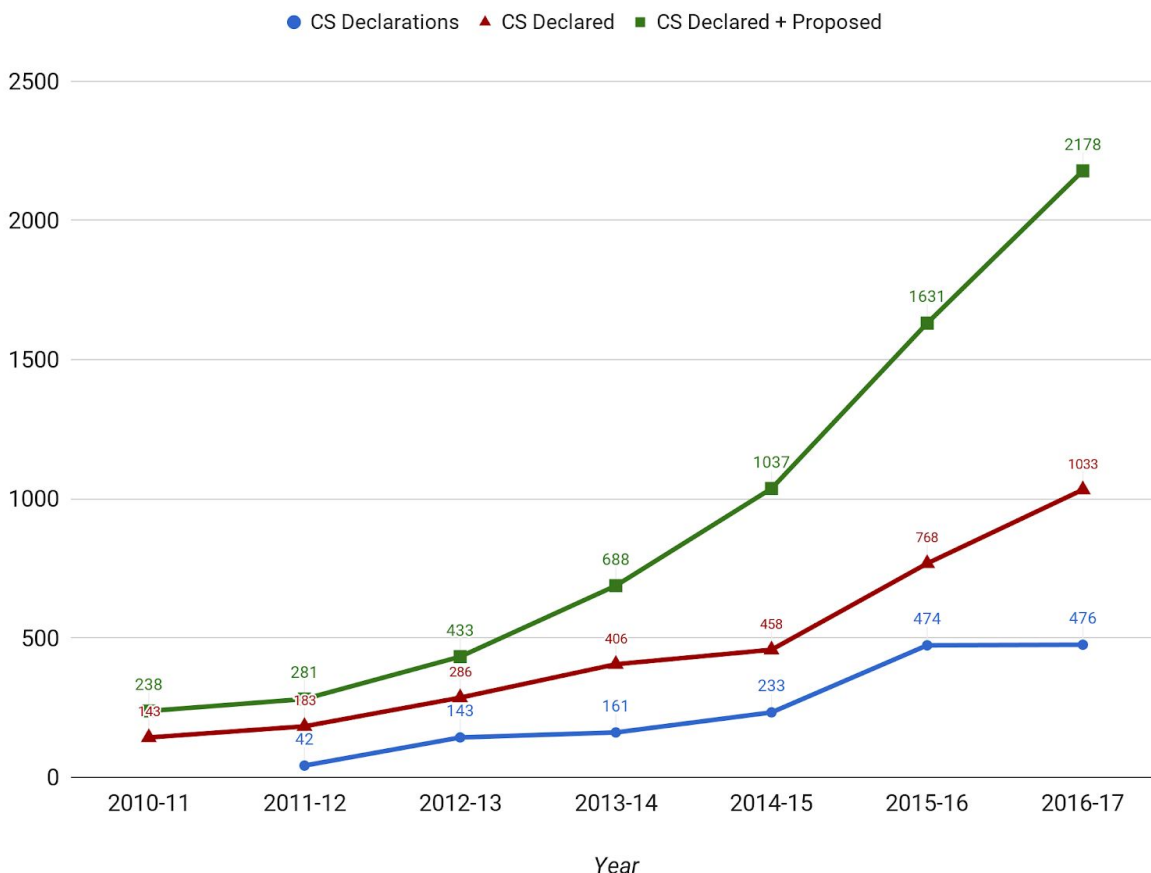


Figure 1: Number of yearly CS major declarations (blue, includes both BS and BA), number of total enrolled CS declared (red, includes BA, BS and transfers), and CS declared or proposed (green) majors, 2010 to 2016 (data from SOE data analysts based on the Student Universe of the Data Warehouse; see [source](#)).

Figure 1 illustrates the growth in our undergraduate student body. In spite of the several measures we have taken, and which are detailed later, this exponential growth is outpacing our teaching capacity. We have had to steeply increase class sizes, modify classes in ways that are not beneficial to students (for instance, simplifying assignments, doing without project components, and resorting to peer grading). Yet, students are experiencing more and more difficulties getting into the classes they need to graduate on time. As the surge in declarations will work through the system (see Figure 1 again), we expect the situation to grow worse before it can get better.

We note from the figure that the number of CS declarations in 2016-17 equals that of 2015-16. We believe that this is the result of capacity constraints on the offering of required classes, such as CMPS12A and CMPS12B. In the same period, the number of CS proposed (but not declared) students went from 863 to 1145, so there does not seem to be a lowering or a stabilization yet in the student interest in CS. Furthermore, several key CS classes such as

CMPS 12A, 12B, and 101 are service courses that are a required part of other majors such as computer engineering or computational media, further increasing the strain. Further compounding the problem, it appears that students that come to UCSC intending to major in BSOE degrees but are not able to declare tend to leave the campus rather than switch majors (see Figure 7), adversely affecting the campus graduation rates.

In addition to this undergraduate load, the CS department has one of the largest graduate programs on campus, with 104 PhD students and 85 master students. The extreme undergraduate teaching load represents a main impediment to the further expansion of the graduate programs. Indeed, CS receives over 800 MS applications yearly, but of those, it is able to admit only a few dozen each year due to capacity constraints. If the undergraduate student to faculty ratio were not so extreme, it is likely that the CS department could use the surge in interest in CS master degrees to develop a large and successful MS program that could bring much revenue to the campus.

In the eyes of the students

To better realize the situation of the CS major it is useful to take a look at some typical classes, and at comments by students seeking to enroll in classes. The comments have been edited only by removing the student's names, to preserve their privacy.

CMPS 121 (Mobile applications). This class went from 57 students in 2012, to 230 students in 2017 with a waiting list of 70. 2016 was the last year in which every student could do a project. These are comments from students who are begging to be allowed to take the class:

“I am currently a third year undergrad student at UCSC majoring in CMPS B.S. Sadly my enrollment time is tomorrow at 9 am and every upper division class that I can possibly take to further my education for my major is full at the moment. I'm not really sure exactly what to do at the moment as I can't take any classes for my major but I thought I would go ahead and ask if you had any power to help me into your class.”

“It's the only CS-related class that has a waitlist less than 60 people and it's possible for me to take in this spring.”

“At the moment, I will not be able to graduate on time because of the situation. I want to go into the mobile applications field after graduation and want to use this class as my upper div elective. Also there are no other upper div CS classes available for me to take as they are all full so I can't continue the CS major.”

“Since I came to UCSC, I have always faced difficulty in getting any Computer Science upper-division classes. Even with junior year standing, CS 121-01: Mobile Applications was already full when I was allowed to enroll for my classes for the Spring 2017 academic quarter. I would be extremely thankful for a permission code because I want to focus on Mobile Application Development. I want to intern or work for companies such as Appstem, King (Activision Blizzard), Snap, or Instagram. I am going in my third academic school year yet I am still facing stiff competition amongst the increasing population of Computer Science non-transfer and transfer students.”

"I need this class in order to satisfy the 2 CGE pre-requisite for the capstone course in Game Design. If I cannot get my second CGE then I cannot take my 3 quarter capstone sequence, and will not be able to graduate on time, and will have to wait a whole year to take it in my 5th year."

CMPS 183 (Web Applications). This capstone class went from 70 students in 2012, to 200 students in the Fall section 2016, along with a waitlist of 50-60 students, and more students in the Winter section of 2017. Here are some comments from desperate students trying to get a permission code:

"I really wanted to take web applications courses, since I was in high school. I want to build websites in future. I waited for a long time to perfect my skills and complete required courses to able to take it. But now its seems I won't be able to add this course. I tried to add this course last year and now I don't want to lose this time too."

"I am planning on graduating this Fall, and this is the last class that I need to take to graduate. Not taking this class in the Fall will cost me thousands of dollars in tuition which will come out of my own pocket. "

"I need a permission code so I can fulfill my capstone requirement and be on track to graduating by the end of the year!"

CMPS 185 (Technical Writing and Communications in CS). This course was developed to help students meet their DC requirement. Originally it had an enrollment cap of 35; enrollment has now swollen to nearly double that (58), and yet had an extensive waiting list. Here are statements from students seeking a permission code:

"I am a fourth year CS transfer student on track to graduate at the end of spring quarter 2017. I had my enrollment appointment for winter quarter yesterday in which I attempted to enroll in you upcoming CMPS 185 course, however it filled up before my registration slot even opened. Besides this 185 class, there are currently no other course options for DC requirement in the coming winter and spring quarters. I am hoping that there is a possible resolution and course of action that I can take to allow me to graduate on time."

"I'm a computer science senior hoping to graduate this spring, but I didn't get into CMPS 185, which I need for graduation. It doesn't look like it will be offered again this year, so I'm really feeling stuck. I really don't want to spend another \$10k or so to pick up the DC requirement next year, so I was wondering if I could get a permission code."

"I'm currently on track to graduate this year and have unfortunately not made it into your CMPS 185 class which is necessary for me to graduate. I'm on the wait list as position 17 as of the moment and would like to know if there is any possible way in securing my position into class. I know I could wait until the end of the wait list period but I've had many quarters in the past where this has not worked out to my benefit."

"I would love the opportunity to take your CMPS-185 class in the Winter 2017. I'm currently high (in the 20's) on the waiting list, and it is one of the classes I need to fulfill my DC requirement...I tried getting other DC requirements but was unable to register at"

all for any of them and the seats all got taken. Is there any way there will be more spots opening up? Or another section being taught this quarter or next? I really don't want my graduation delayed so long... It's so hard getting CS courses here."

"I am a Computer Science BS Undergraduate who is in his senior year. I am expecting to graduate in Spring 2017, however, I still need to fulfill my DC requirements. Looking at the UCSC Computer Science Course Web Page, it seems like CS 185 is the only class that is offered for the remaining of the year that also fulfills the DC requirement. I was planning to take CS 185 in Winter 2017, however, the class was full before I was even able to sign up."

Why are CS student numbers going up?

The biggest long-term reason for the increase in our student pool is likely demand from industry, as well as the ever-growing role of information technology in every industry and production sector. We remark that the increasing demand is also making it harder for us to retain faculty and recruit qualified lecturers. Fields that once relied on labor, such as agriculture, now use sophisticated software to monitor fields, automation and drones to survey and spray them, and more technology to harvest them, package the products, and distribute them. Even white-collar fields such as paralegals are experiencing the effects of the inroads of automation and information technology. As this happens across fields, prospective students take notice, and strive to maximize their computer science expertise.

In Figure 2, we compare the growth of the SOE CS and CE departments¹ with the average growth of departments participating in the 45th CRA Taulbee Survey². The CRA Taulbee Survey is a survey of PhD-granting CS, CE, and Information departments in the United States and Canada; in 2016 the survey solicited data from 266 departments, of which 178 responded. Figure 2 shows that the growth of the number of students in the UCSC CS department tracks very closely the average growth of departments with at least 25 tenure-track faculty, while the growth in CE students tracks closely the growth of departments below 25 tenure-track faculty. This shows that the growth in number of students is a national trend that has lasted for over 10 years, and shows no sign of stopping.

An influential study that documents this phenomenon is the STEM report issued by Georgetown University's Center on Education and the Workforce³. This survey laments the shortage of STEM (Science, Technology, Engineering, and Mathematics) majors -- a common refrain these days -- and, interestingly, predicts that by 2018 more than half of STEM jobs will be for computer specialists. University of Washington's President Ana Mari Cauce talked about the increasing demand for CSE degrees from students, saying that she is not worried about potential changes in the job market because CSE degrees are "very flexible": "I am not a gambling person, but this is a sure bet", said Cauce in [an interview to GeekWire](#) in 2017. Last year, CSE became the leading first-choice major among confirmed incoming UW freshmen. UW says it currently has to turn away two out of three qualified student applicants to the CSE department.

¹ The data from SOE is from Infoview/Student Universe/Major/SOE-historical 3 QTR average.

² Available at: <http://cra.org/wp-content/uploads/2016/05/2015-Taulbee-Survey.pdf>

³ Available at: <http://www9.georgetown.edu/grad/gppi/hpi/cew/pdfs/stem--complete.pdf>

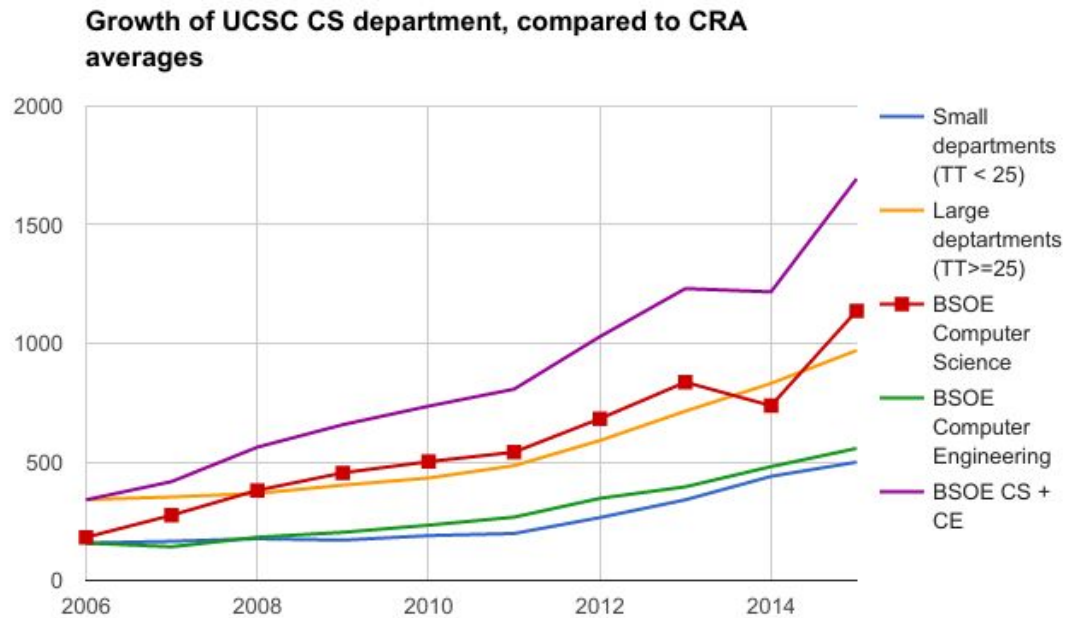


Figure 2: Undergraduate student growth of BSOE CS and CE departments, compared to averages for small and large CS, CE, and I departments in the United States and Canada. BSOE majors include both proposed and declared majors; the data are averages over the three quarters. TT is an abbreviation for tenure-track faculty.

Additionally, the CS programs at our sister campuses either tend to reside in Engineering Schools that control the number of CS students admitted or have already been declared impacted. Thus students interested in CS are forming an increasing fraction of our applicant pool, and tend to have a higher conversion rate (admission to SIR to enrollment).

The startling pace of growth in our numbers might evoke the “dot-com” boom of the late 1990s, when CS enrollments also rose. One might thus wonder whether we are experiencing a similar short-term phenomenon. While it is difficult to predict the future, the growing role of information technology in our society is a long term trend that will continue, and with it, we expect the growth in popularity of STEM and CS to also continue. Quite simply, humans are going from doing jobs themselves, to teaching machines how to do jobs for them, and the latter involves many CS skills, from programming, to machine learning, to data organization, in fundamental ways.

Enrollment Caps for the CS Majors (BS, BA)

The computer science department requests that the number of incoming frosh with a proposed CS BS and BA majors be limited to 475. According to historical trends, we expect that this will yield 350 frosh students who end up declaring CS BS, and about 50 declaring CS BA at the end of their sophomore year. We justify this enrollment cap in two ways: first and foremost, with a capacity analysis of the CS major; second, as a sanity check, via comparisons with both North-American CS departments and other UC CS departments, which show that even under the proposed enrollment cap, the workload at UCSC CS will exceed or be at the top of the range of the workload at comparable institutions.

We note that this cap is chosen with the assumption that CS can continue to make use of the extra TAs allocated centrally from campus (38 TAs/year); without these additional TAs, the cap would need to be lower.

Please note that we are not proposing to limit the number of incoming transfer students. As about 175 students transfer yearly into CS, the proposed cap on incoming frosh will mean that CS will have 2 students declaring a CS BS major for each entering CS transfer student.

UCSC CS Capacity Analysis

In conjunction with the Associate Deans for Undergraduate and Graduate Education in the School of Engineering, the computer science department has developed an accurate capacity model, which predicts the enrollment in CS classes as a function of the number of incoming CS students. The model can be accessed online at [this link](#).⁴ The model predicts class enrollments, and TA and instructor/lecturer positions needed to teach the enrollments. The model also computes the number of lecturer and TA slots available to the department via the current financial model of resource distribution, and thus, allows us to determine the extent in which the CS department needs auxiliary resources to deliver its curriculum.

The main input to the model is the number of students that, each year, declare a CS BS major. The following table reports the main outcomes computed for different values of this number.

Description	Model Values		Notes
	Proposed: 350 declarations /year	Comparison: 400 declarations /year	
Number of CS BS declarations per year	350	400	Model input

⁴ For confidentiality reasons, users must be logged in via their @ucsc.edu account to view the model.

Incoming transfer students	175	175	Meets 2:1 transfer ratio, and is small increase on current number (about 175).
Total number of seats	11,582 (1,287 student FTEs)	12,256 (1,363 student FTEs)	Includes both CS students, and students of other majors who need CS classes.
Total number of undergraduate sections required	77	82	Does not include service classes such as CMPS 10.
Percentage of undergraduate sections taught by ladder-rank faculty	44.4%	41.7%	Lecturers would teach more than half of the classes.
TA Deficit	22	24	Additional TA quarters CS requests from campus to be able to fund CLP
Additional lecturers to be found and hired to be able to deliver 2018-19 CLP	2	3	This assumes no separations of current lecturers will occur.
CS faculty FTEs, and effective faculty FTEs at net of administrative service and sabbaticals	22 effective: 17	22 effective: 17	As of Fall 2017. CS is hiring for 2 positions, and it is likely to lose 1 FTE due to retirement by June 2018.
Undergraduate Student FTE / Faculty ratio	58.5 effective: 64.3	62.0 effective: 68.1	Computed wrt total and effective faculty counts.

The CS department proposes a target for CS BS declarations of 350, or 400 combined BS and BA declarations. Accounting for about 20% melt from incoming freshmen to declarations, this suggests limiting the incoming frosh CS to 475 per year.

We observe that the student FTE to faculty FTE ratio of 58.5, computed with respect to all CS faculty (including those not active in the department), is **about twice the campus average of 29:1⁵**; it reaches 64.3:1 if we consider only faculty serving in the department. We think that stabilizing the ratio at around 58.5:1 is appropriate in the short term, but we stress that it is not

⁵ This is an apples-to-apples comparison. According to the most recent IRAPS Instructional Workload Report (for the 2015-2016 Academic Year) UCSC had 529 permanently budgeted faculty and delivered 15,808 undergraduate FTE of instruction, which is equivalent to a 29.8:1 ratio. For 2016-17, IRAPS data gives 16,488.1 undergraduate FTEs, and 571.66 senate faculty FTEs (this number is pending finalization but is accurate within a few percent), leading to a 28.84 undergraduate student FTE to senate faculty FTE ratio.

sustainable in the long term, as it still corresponds to a severely degraded experience for students.:

- **Percentage of classes taught by ladder rank faculty.** Even with a cap of 350 BS declarations/year, ladder rank faculty are teaching less than half of the undergraduate classes taught in the CS department. UCSC still prides itself in the quality of its undergraduate education, but this pride is hard to justify when faculty are doing only a minority of the undergraduate teaching.
- **Need to recruit and mentor lecturers.** Due to market conditions in computer science, finding qualified lecturers has been a challenge, and the challenge has recently increased due to the tightening of visa regulations, restricting access to international candidates. Attempting to hire 2 or more lecturers in a year presents a high level of risk, as there is no guarantee we can fill the positions. In no previous year did we manage to hire 3 lecturers. Furthermore, the time required to recruit and mentor the lecturers places a great burden over a faculty already stretched thin by the student-to-faculty ratios.
- **Level of risk to the CLP.** More lecturers mean that, if one of them becomes unavailable due to separation from UCSC, illness, or visa problems, 6 sections may need to be cancelled or merged into others. As class sizes have grown, the physical ability to merge classes decreases (there is often no classroom where to fit the merged class), let alone the educational consequences. Even under the proposed limit, extrapolating from past level of instability in the CLP, we expect to have a few large class cancellations per year after student enrollment (or even instruction) has occurred. The greater the reliance on lecturers, the greater the instability.
- **Quality of education.** The 58.5 student to faculty ratio far exceeds the campus target, and places the CS department below the bottom 10% percentile of comparable institutions with respect to quality of education, as we will see in detail later. UCSC aspires to be better than the bottom 10% of comparable institutions.
- **Faculty access in capstone and project classes.** The quality of our capstone classes is crucial to the success and future employability of the students. These are the classes where students and faculty get to work together, students directly benefit from faculty interaction, and the faculty are then able to give the personalized guidance, and subsequently write the letters of recommendation, that are critical for the future career of students. This access to research faculty is one of the main attractions of UCSC for students. We have already had to expand many capstone classes beyond the size in which this interaction is effective, which we find to be about 60 students.

In order to address these issues we would like enrollments to stabilize around 45 student FTE for each permanently budgeted faculty FTE in the medium term. We would prefer if this were to happen by a growth in the number Senate faculty in the department. However, we are also willing to further constrain enrollments if that is the only way in which we can achieve the target.

Model Assumptions

The model has been developed under the following assumptions:

- The computer engineering (CE) and computational media (CM) cohort sizes, and that

the number of transfer students, will experience comparatively slower growth consonant with recent historical patterns. This is a somewhat optimistic assumption, as students denied admission to the CS majors might start to apply to the CE and CM programs.

- Service classes, such as CS 10 or any general education (80 level) class, that the CS department would like to resume teaching are not included in the model. Thus, the model is conservative with respect of teaching load.
- The class sizes have been validated with respect to the educational needs of students in the CS major. Large class sizes are used for lower-division classes, and somewhat smaller sizes are used in upper-division classes, especially where project requirements make large class sizes unfeasible. In any case, the model is not very sensitive to class size. The main consequence of setting enrollment for all lower-division classes to 350 (even assuming there were sufficient large classrooms) is that slightly fewer TAs, and one fewer lecturer, would be required. On the other hand, if we lost an instructor at the last moment for such a large class (an event that is happening with some regularity), we would be left with few options other than cancelling it. The need for some flexibility has been built into the model.

UCSC CS Comparative Analysis

To put the limit of 475 students / year in context, it is useful to see how the UCSC CS department compares with similar departments in North America. For this, we use data from the 2017 CRA Taulbee Survey (<http://cra.org/resources/taulbee-survey/>), the main survey of enrollment, graduation, and department statistics for computer and information sciences, conducted since 1974 in North America. The [2015 survey](#) covered 266 PhD-granting departments, and received response from 178 of them; the response rate from US CS departments was 77%.

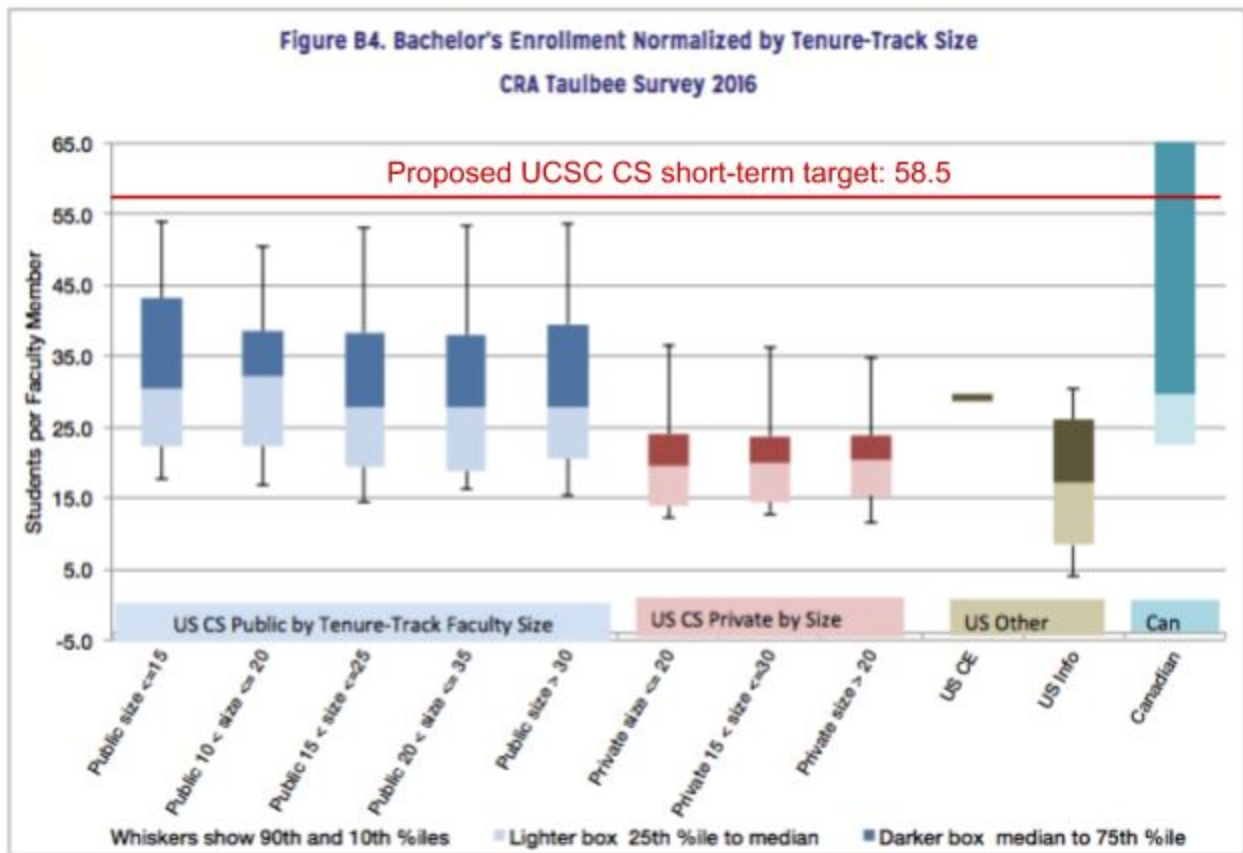


Figure 3: Bachelor enrollment size vs. faculty size for North American CS Departments. UCSC CS is currently at a 100:1 ratio. This impaction proposal aims at achieving a ratio of 58.5, well above the 90% percentile for public CS departments of comparable size, with respect to total faculty (including the faculty currently serving outside of the department in administrative roles, such as Dean and VCR). With respect to faculty actually serving in the department, the ratio is an even higher 68.1.

From Figure 3, reproduced from the survey, we see that UCSC most fits with CS departments in public universities with faculty sizes from 15 to 25. The current 100:1 ratio of students in the major to CS faculty we have at UCSC in Fall 2017 is not only superior to the 90% percentile: it is twice as high as the 90% percentile, and it is altogether off the chart. UCSC is, quite literally, in

uncharted territory when it comes to serving (or rather, under-serving) its computer science undergraduate population. This proposal aims at reducing the ratio to 58.5 for next year, which is above the 90% workload. The goal, ultimately, is to converge towards the 26:1 ratio goal via long-term faculty growth.

Major Migration into CS

In order for the caps on freshmen being admitted to UCSC as proposed CS majors to be effective, we need to limit the number of students who switch from other majors to the CS major. If this is not done, students will apply to other majors as a pathway to a CS major.

In order to prevent this “backdoor” effect, we plan to put the following regulations in place.

- Students admitted to UCSC before CS admission restrictions are able to propose and declare a CS major according to their catalog rights.
- Students admitted to UCSC subsequently to the adoption of CS admission restrictions can propose and declare a CS major only if they applied to UCSC for a CS major.

CS will monitor the effectiveness of these measures, and if required, it will take measures to increase or further restrict major migration to CS by the students who apply to UCSC without proposing a CS major.

Suggested Admission Criteria

The CS department has conducted studies on what might be appropriate criteria for selecting applicants to be admitted to UCSC as proposed CS majors. In particular, we have performed an analysis of student success, examining the correlation between student data at application time, and “*success*” defined as the ability for a student to declare a CS major within the first two years on campus. The strongest predictors of success, in our analysis, were seen to be the High School GPA, and the Math SAT score, of the student. A simple yet powerful predictor of student success consisted in the quantity called $satgpa = (SAT\ Math / 800) * (HS\ GPA / 4) = SAT\ Math * HS\ GPA / 3200$.

Figures 4 and 6 show the correlation between $satgpa$ and probability of success of students for the student cohort entering UCSC in Fall 2014. The data shows a sharp upturn in the probability of student success for values of $satgpa > 0.7$, so this could form a reasonable selection criterion for students. In particular, we note how students with $satgpa < 0.7$ have a probability of success lower than 30%.

Figure 5 reports the correlation between Math SAT score and outcome in various classes for students entering in Fall 2014, following the classes they have taken until their junior year. We see a strong correlation between Math SAT and outcome in the foundational CS classes (5J, 11, 12A, 12B); few of the students in the lowest quartile of Math SAT scores make it to CMPS 101 by their junior year, as indicated from the size of the bubbles for the various quartiles.

Students who come to UCSC to pursue a CS major, and fail to declare CS, by and large end up leaving the university. Figure 7 shows that most students that enter UCSC as proposed CS majors, after two years, are either declared CS majors, or remain proposed CS (and may leave in future years), or leave UCSC. The great majority of students who were CS-proposed in 2014 were either in CS (proposed or declared) in 2016, or had left the campus. Successful migration to other majors was only 14%, of which 4.7% in SOE and 9.3% outside. Thus, CS is not a main intake channel for majors outside CS, and limiting the number of students admitted to CS will not negatively impact the students that flow to other campus majors.

For the majority of these students, following a different career path early on may be preferable to joining UCSC. They leave with broken dreams and often student debt. Many such students would have been better off by either pursuing other majors for which they were better prepared from the start, or by accepting admission from other academic institutions, including community colleges, where they would have been able to make up for weaknesses in their preparation by learning in smaller classroom environments, and then possibly transferring to UC later via the transfer pathway.

In addition to the frosh coming in as proposed majors, an additional 38 students declared the CS major (22% of the CS major declarations). Most (29) entered as undeclared students, with the remainder entering as proposed majors in PBSci (6 students) and Social Sciences (3 students). After two years, 24 students migrating into our program were still proposed majors. Again, the largest group (9 students) entered as undeclared, with another 8 coming from PBSci, 4 from Social Sciences, 2 from Arts, and 1 from Humanities. The total migration into our program (62) exceeded the number of students migrating into other campus programs (52).

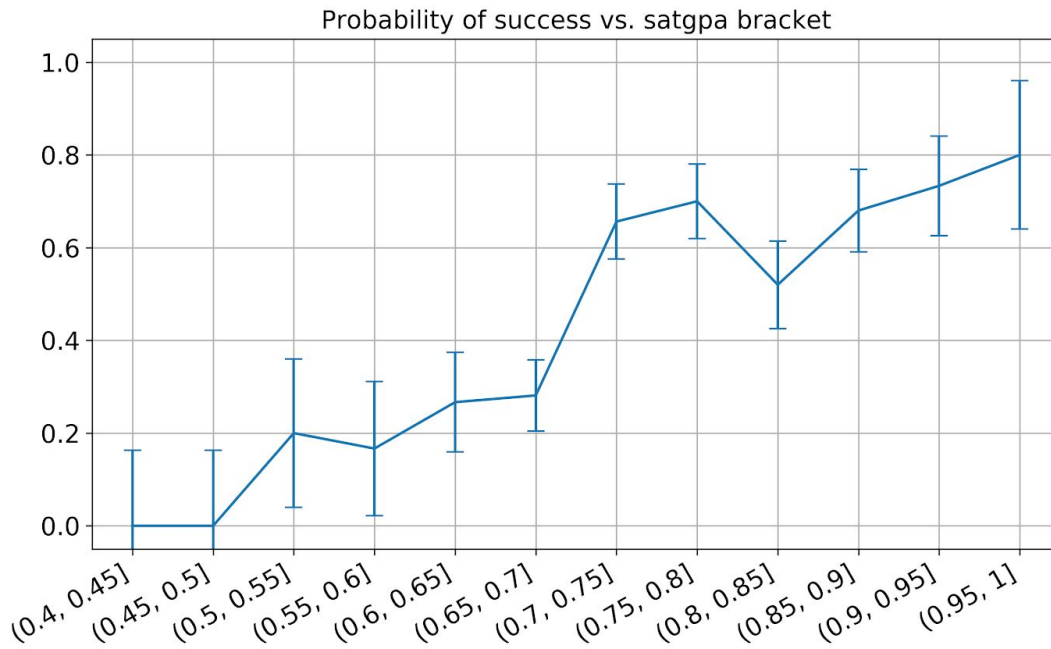


Figure 4. Correlation between satgpa = Math SAT * HS GPA / 3200 and student success, defined as the probability of CS-proposed students of declaring a CS major. Error bars indicate one standard deviation. There is a sharp upturn in probability for satgpa > 0.7.

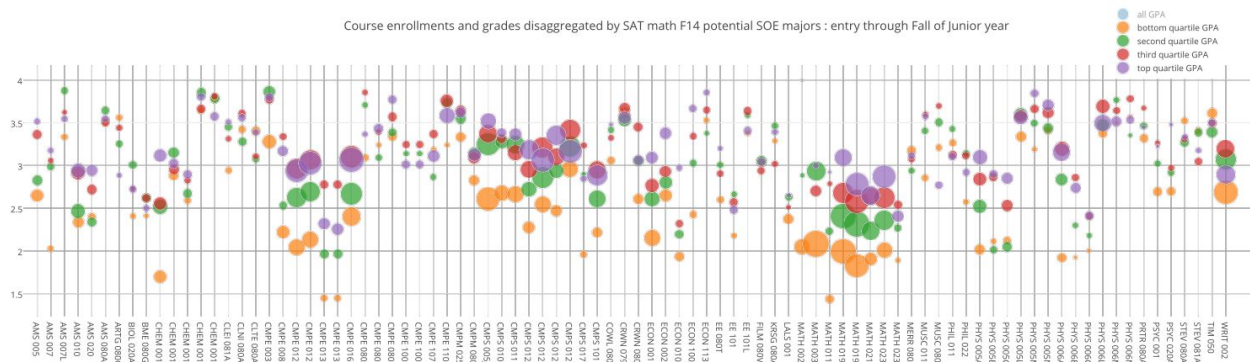


Figure 5: Course enrollments and grades, entry in Fall 2014 to junior year, disaggregated by Math SAT score quartiles. Violet is the top quartile, red is the second (from top), green is the third, and orange is the bottom quartile. The area of a bubble is proportional to the number of students.

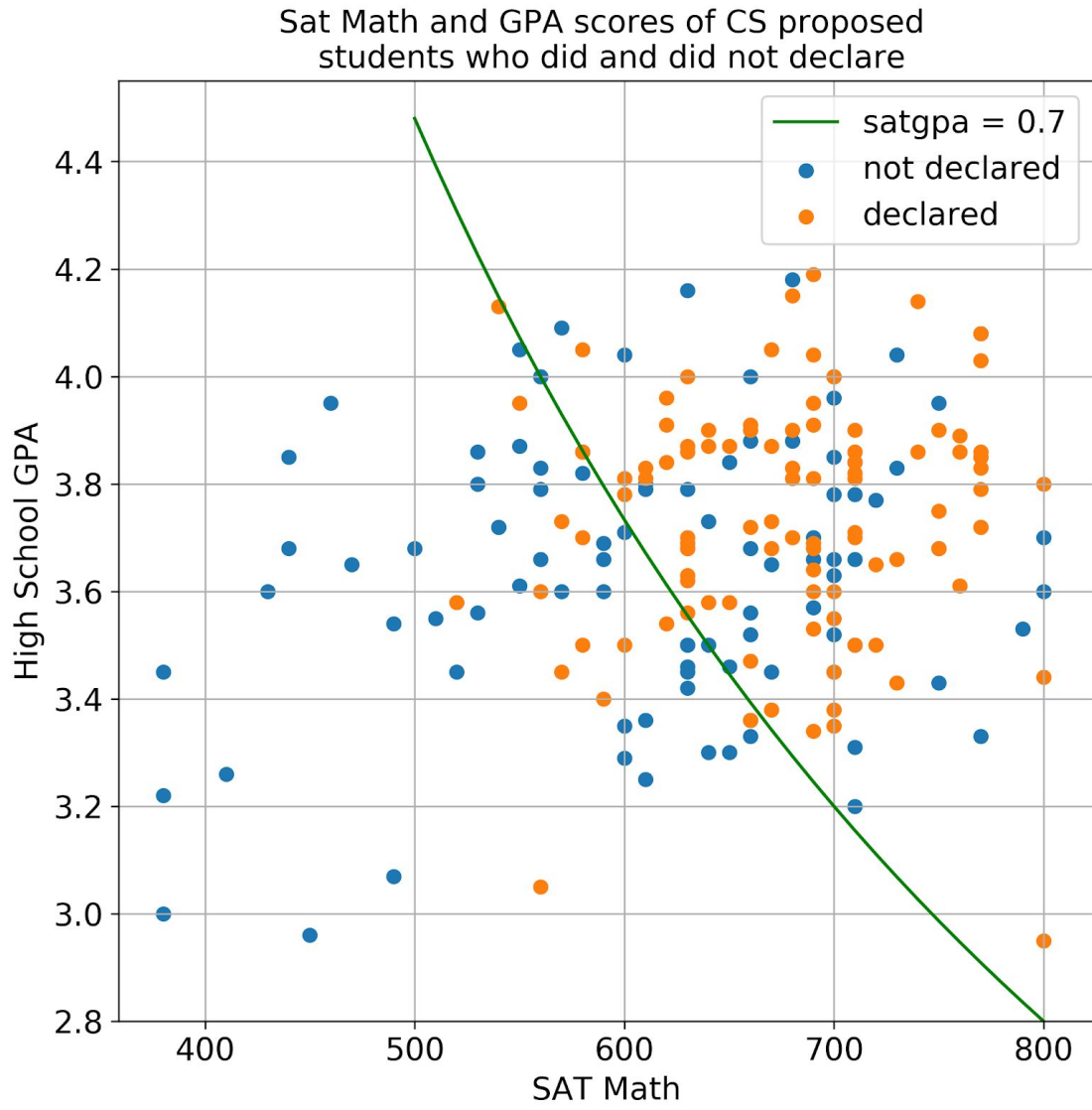


Figure 6. Student success (declaring a CS major after proposing a CS major) as a function of SAT Math and High School GPA. Points represent individual students in the cohort entering UCSC in 2014.

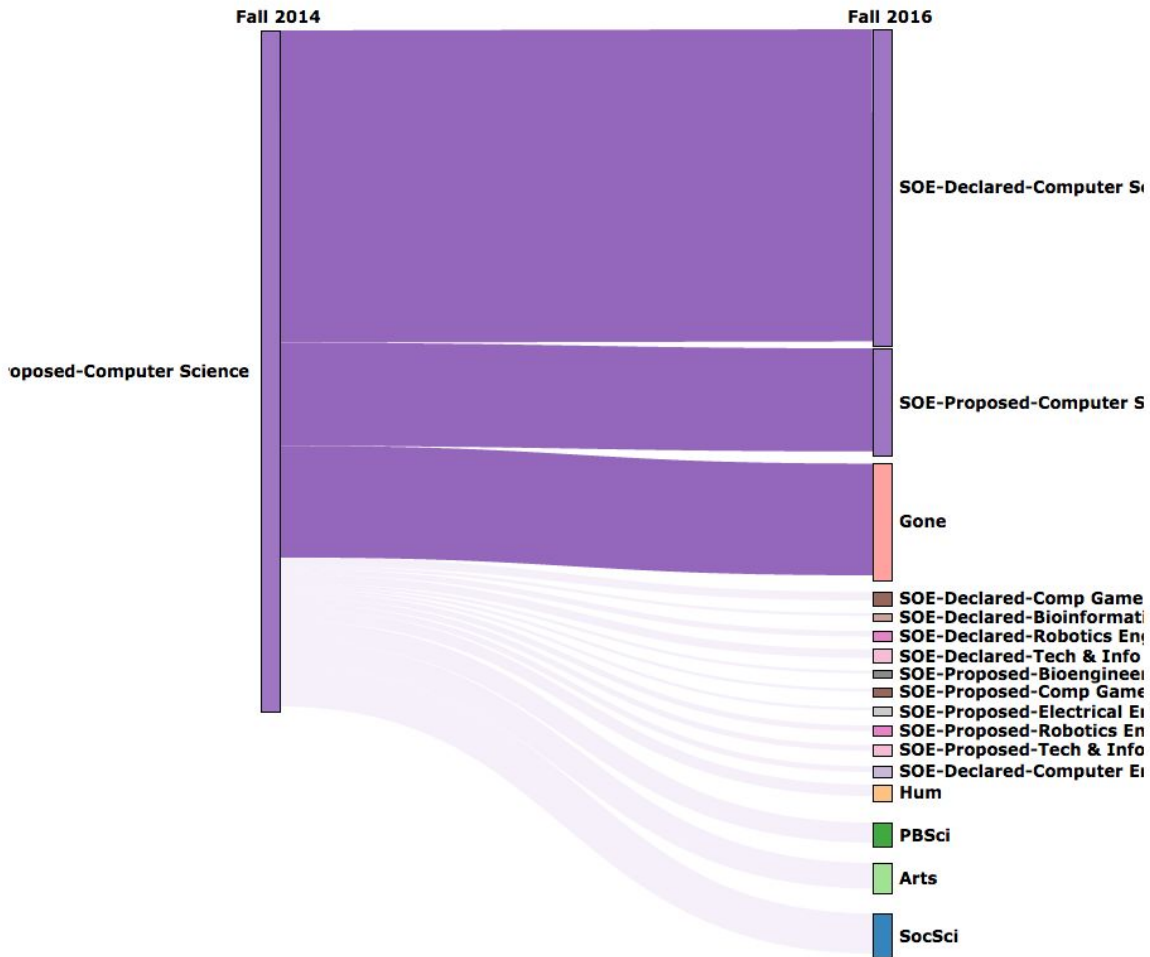


Figure 7. Destiny of students trying to declare the CS Major. Most of students who join UCSC as proposed CS end up either declaring CS, or remaining proposed CS, or leaving. CS is not a major pathway to other majors.

Impact on Diversity

Figure 8 illustrates that under the current admissions regime (blue bars), Hispanic or Latino students admitted to UCSC have less than half the probability of success as White or Asian students. Therefore, the damage we do by admitting weaker students in the CS major falls disproportionately on such minority students. If we select students with $\text{satgpa} > 0.7$ (orange bars), the probability of success becomes much more uniform by ethnicity.

Figure 9 shows how the imposition of a $\text{satgpa} > 0.7$ requirement would have only a modest effect on the ethnic composition of the students who can successfully declare CS by the end of their second year on campus.

The contra-positive to this analysis is that our data also shows that, as the admission criteria are

made even more stringent, with even higher thresholds for high school GPA and Math SAT score, there is a clear discernible effect on both ethnic and gender composition of the successful students. For this reason, we stress that the long-term solution to the student overload in the CS major must consist in an increase in teaching capacity (more faculty FTEs), rather than in permanent restrictions to admissions.

As the shift in student interest towards computer science, and engineering at large, continues, only a strengthening in the teaching and mentoring capabilities of the CS department can enable UCSC to fulfill its mission of teaching to a diverse student population, accepting its due share of California high-school graduates.

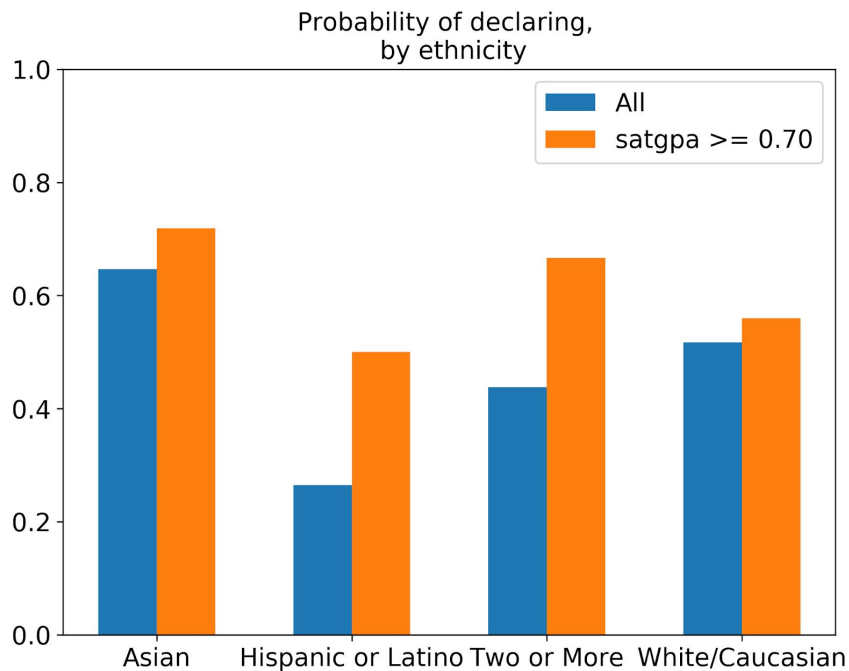


Figure 8. Probability of success by ethnicity, before (blue) and after (orange) imposing a satgpa > 0.7 requirement.

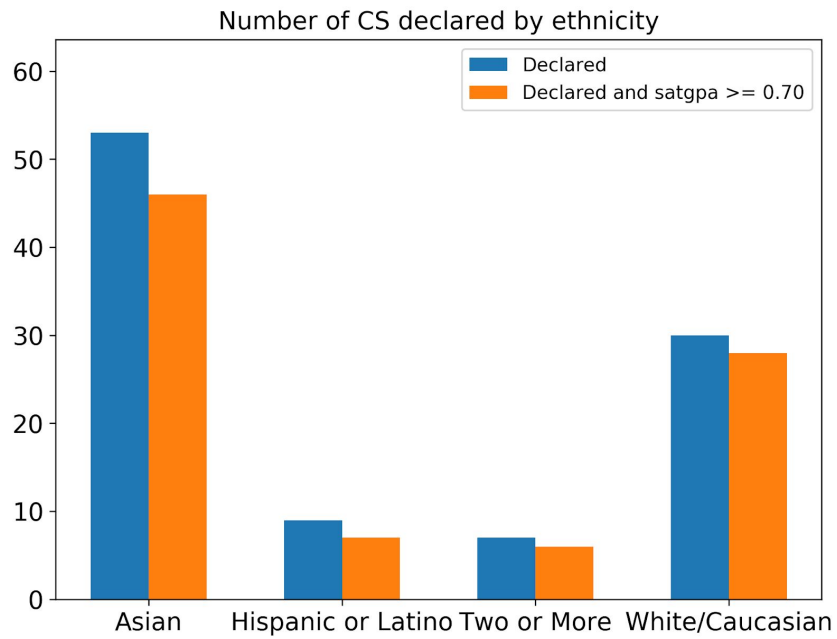


Figure 9. Number of declared-CS students, before (blue) and after (orange) imposing a satgpa > 0.7 requirement.

Appendix

We present here a summary of measures taken to try to accommodate growth in the CS majors. The scheme here follows the campus recommendations for managing curricular capacity.

Resource allocation. The department has made extensive use of enrollment planning tools to plan the number of offerings of classes in order to meet demand. Furthermore, the department has made extensive use of enrollment tools (such as different enrollment opening dates for students in different stages of their major) to ensure that enrollment in classes is offered with priority to the students for whom the classes are required for their major. This has allowed the CS department (and other departments in the School of Engineering) to cope with demand at least in part. Many classes still experience considerable waiting lists nevertheless.

The department has successfully hired its first LSOE in 2016-17, and is striving to hire both more ladder-rank faculty and more LSOEs.

Streamline the curriculum. There is a marked difficulty in making changes in the curriculum at times of extreme surge in demand, as a majority of the teaching is done by lecturers that need to teach along proven syllabi in order to be at their most effective. The time when a class is offered in multiple parallel sections is not the easiest time when to experiment with curricular change. Furthermore, the faculty that should be responsible for curricular planning are instead busy trying to adjust their own classes to the increased demand.

In spite of these difficulties, the CS department has streamlined the undergraduate curriculum, ceasing the teaching of general service classes that are not core to the CS curriculum. The main capacity constraint, at this point, is however due to the classes that form the very core of the CS curriculum (12A, 12B, 101, 102), as well as the classes that form the fundamental pathways to graduation, such as the capstone classes. Due to our above mentioned capacity planning, there is no single point of pain; rather, there are long waiting lists throughout. The CS department is embarking into a major revision of its core curriculum (11, 12A, 12B, 101), and we expect to file new program statements and class revision proposals in Fall 2018. This revision will lead, we hope, to better educational outcomes, but it is unlikely to create more teaching capacity.

Instruction delivery. The CS department has markedly increased class sizes to cope with the increase in demand. Many classes that used to rely on teacher-student interaction and projects have been transformed into large classes with peer-grading or automated grading for homeworks, and no or optional project components. The peer-grading tool CrowdGrader has been developed within the department in order to enable the evaluation of complex coding homework, where automated grading is not feasible. Lectures for large classes are often recorded, allowing students more flexibility in class attendance.

As an example, CMPS 121 and CMPS 183 were small project-based classes enrolling fewer than 80 students 4 years ago, and now enroll well over 200 in each offering, and are offered multiple times a year. CMPS 101 is now offered 4 times a year, CMPS 12B is offered 6 times a year (two sections in each quarter), and all of the offerings have capacity well over 200. Indeed, an exam of the [capacity model](#) we developed is based on class enrollments of 200-350 students

for all but advanced electives.

Summer courses. We have made progress in offering Summer courses: in Summer 2017, many of our basic classes were offered, including CMPS 5J (42 enrolled), CMPS 12B (147 enrolled), CMPS 101 (107 enrolled), CMPS 109 (51 enrolled), CMPS 115 (63 enrolled), and CMPS 182 (45 enrolled).

Increase pathways to graduation. The department is considering the institution of a honors program. The issue is that we currently lack the capacity to offer separate versions of advanced classes to honor students. We already have a dual BS and BA track.

Institute clear and timely appeals process. We believe we have a fairly effective appeals process, and we do not think that the ability of students to appeal is a large factor in the teaching overload.

Strictly enforce declaration deadlines. We are drastically limiting the number of appeals to deadlines we grant.

Major course restrictions: We are restricting enrollment to critical classes to students for whom the classes are a major requirement by enforcing differential sign-up times for students according to their major and status. We are considering offering CMPS 12A, CMPS 12B, and CMPS 101 only to students who require these classes for their major, and we are coordinating on this point with the Associate Dean for Undergraduate Studies in SOE.

Restrict double majors: The number of double majors is relatively small, and lead to some of our better students and may improve diversity. Late double majors are approved by petition only.

Institute Preliminary Qualifications. We have recently introduced in the School of Engineering a first-year gating requirement, which may be successful in screening students that are unable to do reasonable progress towards their major in their first year. The requirement states that students in their fourth quarter or beyond who would like to become a proposed major, or students who are proposed and would like to retain their proposed status, must have passed Math 19A or 20A, and two additional BSOE classes from the following list within their first three quarters: CHEM 1A, CMPE 12, CMPE 13, CMPE 16, CMPS 11, CMPS 12A, CMPS 12B, MATH 19B, MATH 20B, PHYS 5A, or PHYS 5C.

Establish Two-Stage Major Declaration: This is done via the above major gating criterion.