Annual Report of the Yale College Student Advisory Committee on Science and Quantitative Reasoning

18 February 2019

Office of Science and Quantitative Reasoning

Yale College Dean's Office

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Executive summary

This committee was convened to advise the dean's office on matters relating to undergraduate education in science and quantitative reasoning. The committee aims to identify and provide evidence for potential areas of improvement in STEM education. To this end, last October, the committee prepared a set of relevant questions, and, in conjunction with the Yale College Council, surveyed the students in the college. The survey received 2439 responses — 44.7% of Yale College. 808 respondents were STEM majors. Our questions asked students about five broad areas:

Reasons for switching out of STEM
More than 50% of each Yale College class enters intending to pursue STEM education. On average, only 70% of students originally intending to study STEM remain in a STEM field. Overall, female and first generation or low-income retention rates seem to match closely with the overall retention rate for each cohort. However, the retention rate in minority ethnicity groups seems to be consistently lower than the other averages. The majority of students who responded explaining why they switched either said that other majors were more interesting (66%) or that introductory classes were not interesting (40%).

Knowledge of resources provided by the Office of Science and QR
Approximately 17% of current STEM majors (204 students), and about 5% of non-STEM majors (111 students), reported that they had made use of the informational resources made available by the Office of Science and QR. Of the students who did utilize the resources of the Office of Science and QR, the overall rating of the informational and financial resources was high.

Experiences in introductory lecture and laboratory courses
Students who switched out of a STEM major had frequently taken introductory lecture and laboratory courses during their time at Yale. 73% of students who had considered a STEM major but was no longer a STEM major by the time of the survey had taken some form of STEM education offered at the underclassmen level, and many students felt that the purpose of these introductory classes was primarily to "weed out" students from the major.

Experiences with undergraduate learning assistants (ULAs)
On average, students (including those who have not used a ULA) report feeling more comfortable asking ULAs for help than graduate TAs Their reported comfort also increases after they've taken a course with a ULA. There was a large demand for more ULAs. We recommend continuing to expand the ULA program.

General experiences with their specific major
Student sentiment towards different aspects of the major and department varies among the different STEM majors. In general, students from the computer science, engineering, and applied math departments tended to be less satisfied with their department, although the particular rankings changed with each question. On the whole, reviews were positive. Averages across all STEM departments on all questions was above a 3 ("average"). Across all STEM departments, the responsiveness of departments to undergraduate feedback rated the best (3.705 average) while the selection of electives rated the worst (3.403 average).

Recommendations and actionable suggestions

To retain undergraduates in STEM majors, our committee suggests a Peer Mentor system, where volunteer upperclassman peer mentors are available to students in each major as sources of guidance and information. We believe this can help address the issues of underutilization of the resources of the Office of Science and QR, as well as help students navigate introductory courses. Peer mentoring programs such as this are being started by some departments, especially in the MB&B department. Other departments, such as applied math, math, and computer science, are considering implementing the program through the help of Departmental Student Advisory Committees (DSACs); we hope to see this useful resource implemented by all STEM departments.

We received a large volume of comments looking for better trained ULAs capable of providing better assistance. We must therefore encourage more training sessions to be provided for ULAs. We must also emphasize that an adequate number of ULAs must be hired for each course. We understand that this can be difficult to estimate during shopping period. Nevertheless, in light of student comments highlighting a lack of ULAs as a major issue, we recommend making liberal estimations, based on past course enrollment numbers.

We recommend increasing the diversity of faculty across all STEM majors, particularly in the departments of Mathematics and Computer Science. More broadly, students have also expressed a need for more electives to be offered and for course sizes to be smaller. We encourage departments to publicize extant research opportunities earlier. A combination of a Departmental Student Advisory Committee and a Peer Mentor initiative for each department should be able to further address department-specific concerns. Specific departments that were relatively consistently low-rated across the questions we posed [department support, department responsiveness, departmental events, undergrad research, diversity, electives] included Computer Science, Computing and the Arts, Applied Mathematics, Mathematics, and Chemical Engineering. The measures we recommend here may be particularly helpful to these departments.

Authority of this committee & intended survey outcomes

This committee was charged in September 2018 by Associate Dean of Science and Quantitative Reasoning Sandy Chang, MD, PhD. The committee's purpose is to advise Associate Dean Chang on matters relating to undergraduate education in science and quantitative reasoning. The committee is intended to provide the Yale College Dean's Office with student input and policy suggestions with regards to STEM education in the College. The 12 members of the committee were asked by the Associate Dean to survey the community of STEM students in the college as to their experiences, and then report its findings. It is on the basis of this survey that the committee sets forth the following recommendations and conclusions.

The survey was conducted in conjunction with the Yale College Council, which facilitated the collection of high-quality data. The advisory committee hopes that the below findings will motivate and guide stakeholders in the several STEM departments and the Yale College community to take actions to better the quality and experience of undergraduates. The committee recognizes that Yale is already an exceptional place to study the scientific and quantitative fields as an undergraduate. However, there continue to be challenges in STEM education, and while none of these challenges have clear solutions, the first step to resolution is acknowledgement of students' most pressing issues. It is our goal to improve the undergraduate experience by recognizing any problems the college has encountered. The quest to perfection and preeminence in these fields is a challenging one, and it is our enduring hope that the work of this committee will further this same mission. The results of the committee are presented forthwith.

The undertaken survey results were representative of the STEM community at Yale. It achieved a statistically significant response rate. The respondent sampling rate of STEM majors with respect to everyone who filled out the survey was similar to the population distribution of STEM majors relative to Yale College. Students were asked to evaluate their department according to several metrics. Certain data, such as those questions pertaining to the Office of Science and Quantitative Reasoning, were aggregated across STEM fields. The survey addressed the success of undergraduate learning assistants; the utility of Dean's Office resources in science and quantitative reasoning; the undergraduate departments themselves; explanations for attrition and students leaving STEM; and introductory laboratory courses and subject sequences.

Understanding why students switch out of STEM majors

The YCC Survey is one of the largest annual surveys done on campus for undergraduates, reaching a total of 2439 undergraduates, or 44.7% of the entire population of the Yale College. 808 of the respondents were from a STEM major, or 33% of the survey respondents. Major by major, the percent respondents for STEM majors was very close to actual Yale college STEM major graduation data from 2016. In addition, the representation of various minority groups was well represented on the survey: 55% of survey respondents self-identified as being on financial aid, while the Yale Office of Financial Aid reports that 50% of Yale undergraduates receive some form of need-based aid. 26% of respondents identify as coming from low-income backgrounds and 21% identify as being first-generation, whereas the University reports 20% are low-income and 18% are first-generation throughout the entire student body. Proportions of minority ethnicity groups, include Asian, Hispanic, Black, and Middle Eastern are close to actual numbers for the university.

Retention rate in STEM by various identity groups

Students enter Yale College with a variety of different motivations, and a large portion of them enter with the intention of pursuing STEM education. 58.2% of the Class of 2019, 52.3% of the Class of 2020, 58.4% of the Class of 2021, and 54.5% of the Class of 2022 intended to be STEM majors when first entering Yale. However, the retention rate of STEM students is subpar. On average, only 70% of students originally intending to study STEM remain in a STEM field, with the Class of 2019 reporting a 72.1% retention rate. The numbers may change for the younger classes, but 68.6% of the original STEM students in the Class of 2020, 71.7% of the Class of 2021, and 69.2% of the Class of 2022 reported that they remained STEM majors as of this past fall semester.

In addition, we were interested in studying the STEM pipeline for different minority groups. We collected these results in the below table. Note that the statistics for single group respondents for Black and Middle Eastern students drops to the single digits, so there may be greater uncertainty for those retention statistics.

Overall, female and first generation/low-income retention rates seem to match closely with the overall retention rate for each cohort. However, the retention rate in minority ethnicity groups seems to be consistently lower than the other averages. Additional retention analysis, in the form of analyzing multiple groups or a distinction by major, may be possible but would be hampered by the smaller number of students with increasingly specific differentiation.

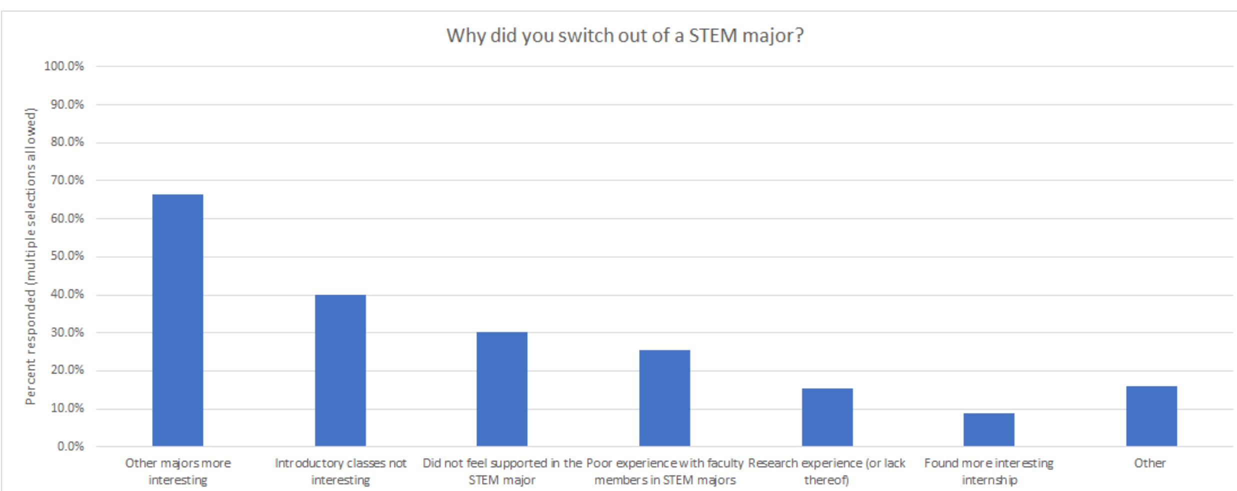
	2022	2021	2020	2019
Overall	69.2%	71.7%	68.6%	72.2%
Male	66.5%	74.1%	68.9%	77.8%
Female	70.5%	68.5%	69.4%	67.1%
White	74.0%	70.5%	66.7%	70.9%
Asian	68.4%	75.2%	73.2%	79.7%
Hispanic	61.3%	63.0%	69.6%	55.6%
Black	57.1%	68.0%	60.0%	42.9%
Middle Eastern	76.9%	66.7%	77.8%	44.4%
First-Generation	68.2%	64.9%	75.9%	69.5%
Low-Income	70.2%	69.0%	69.3%	69.6%

Retention rate: % of students who entered with intention of pursuing STEM education who are currently STEM majors

Comments and motivation for students switching out of STEM

To better understand the motivations of students who switch out of STEM majors, we allowed students to select from multiple options describing their reason for leaving STEM, as well as the option for providing their own comments. Of the 505 respondents who indicated they had once considered a STEM major but are not currently in a STEM major, we received 481 responses to this question.

A majority of respondents, 66.5%, indicated that the switch occurred because "other majors were more interesting", while 40.1% of students responded that they left because "introductory classes were not interesting." Students were allowed to select more than one option, including the option to leave a comment on why they did not choose to continue in a STEM major at Yale. Many of the "other" comments were by freshman who were not yet sure which major they wanted to pursue.



Of the other comments, one common theme was in pedagogy and in support at the introductory level. One comment noted that "Intro courses have a strong 'weed out' mentality and even though I was doing well, I was miserable because I felt like my professors and classmates wanted me to fail," while another mentioned that “I was unable to even attempt to test out of any courses, and decided I didn't want to waste time at Yale re-learning things, and wanted to explore outwards.”

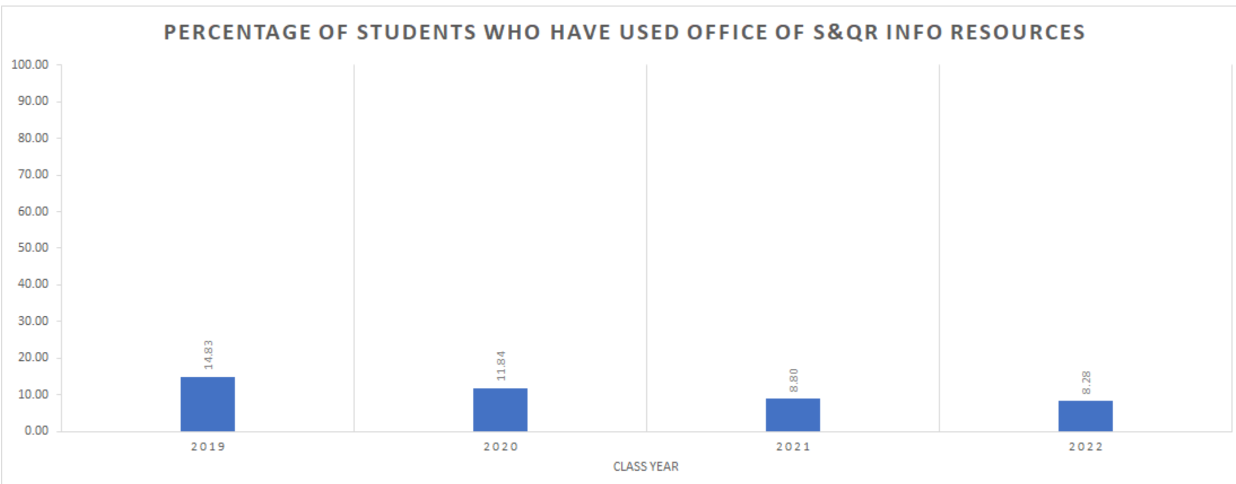
Some of the comments about switching out of the STEM major had less to do with attitudes towards the STEM field, and more towards wanting to take advantage of the breadth of knowledge offered in the humanities during their undergraduate career. One commenter said “I am intending on going to medical school so I am getting enough science and wanted to explore other fields”, while another said “I came in considering STEM but was never really tied to it and never took classes except a few calculus classes and decided against it because social sciences pique my interests more.” Other comments reporting similarly unactionable reasons for leaving STEM included “realized I'm good at STEM but hate it” and “learned I am not STEM-inclined.”

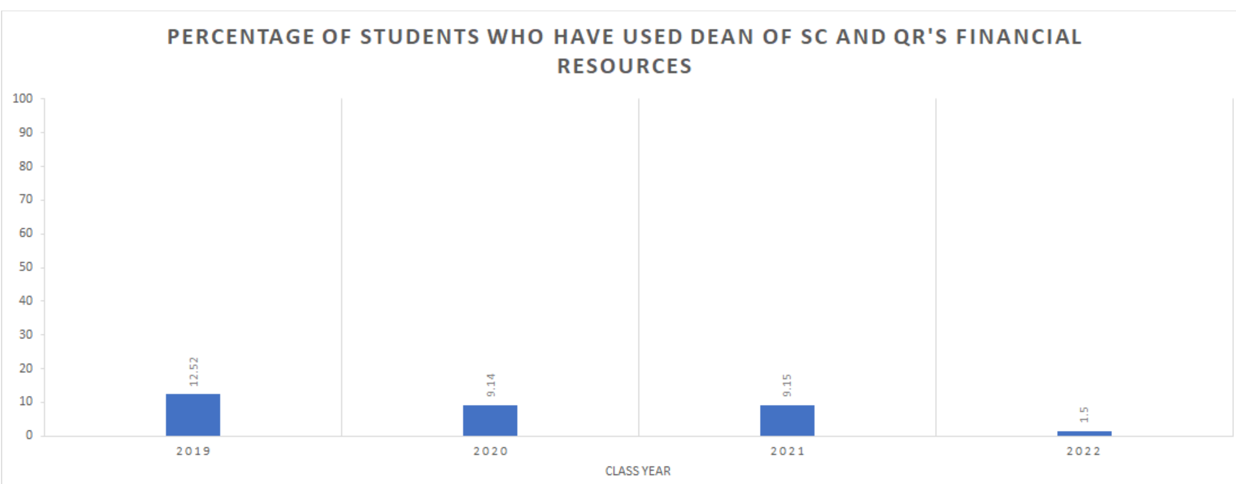
However, there are actionable concerns, notably providing and advertising resources to STEM students in the first and second years. One commenter noted that the STEM major “felt too challenging & didn't know about resources that could have helped me” while another said that they “started major too late to be manageable”. Several other comments echoed the common theme of not finding enough support during introductory classes, or a belief that introductory classes were not doing a good job in teaching material. Some students felt inadequately prepared by their high schools, indicating that disparity in past resources is not yet ameliorated by introductory courses and tutoring, and is a continuing cause of attrition (“Lack of preparedness in STEM from high school”; “Felt inadequately prepared coming out of high school (poor STEM curriculum, even though I’m good at STEM)”). Addressing these concerns through new policy or though the refinement of existing policy could help reduce attrition from STEM majors.

Resources provided by the Office of Science and QR

To gain a general understanding of students' usage and assessment of the informational and financial resources provided by the Dean's Office of Science and Quantitative Reasoning, we allowed students to indicate whether they had used a given resource, and then rate that resource on a 5-point Likert scale.

Approximately 17% of current STEM majors (204 students), and about 5% of non-STEM majors (111 students), reported that they had made use of the informational resources made available by the Office of Science and QR. The usage of S&QR resources is highly correlated with year, where older students report more usage of the resources provided by this office.





Among those students who reported making use of the office's informational resources, the median reported helpfulness was 3 (on a 5-point scale where 1 represents 'Not at all helpful' and 5 represents 'Extremely helpful') for both STEM and non-STEM majors. This corresponded to an average helpfulness rating of 3.94. Approximately 15% of current STEM majors (173 students), and about 2%

of non-STEM majors (46 students), reported that they had made use of the financial resources made available by the Office of Science and QR.

Among those students who reported making use of funding from the Dean's Office, students in STEM majors rated their experience with the funding more highly, with a median score of 4 (out of 5), than non-STEM students, with a median score of 3. STEM majors on average rated the funding 3.85 while the mean for non-STEM students was 3, on the same scale. Overall, both STEM and non-STEM students rated the helpfulness of the office's funding resources at 3.69, on average. While we cannot determine the causes for this disparity in self-reported funding satisfaction, the results suggest that doing so may be a worthwhile endeavor for the Office of Science and QR.

Introductory lecture and laboratory courses

Of the 520 respondents who reported switching out of STEM majors, 379, or approximately 73%, indicated that they had taken at least one introductory STEM course. Among those 379 students, 126 (33%), 111 (29%), 106 (28%), 100 (26%), and 79 (21%) reported having taken an introductory course in biology, chemistry, computer science, mathematics, and physics, respectively. Only 151, or 29%, of the 520 respondents who self-identified as having left STEM reported that they had taken at least one laboratory course. Of those 151, a substantial majority (133, or just over 88%) indicated that they had taken a chemistry lab course. 39 students (26%) reported having taken a laboratory course in physics, and a mere 18 (12%) reported having taken a laboratory course in biology.

Student comments focused around dissatisfaction with their inability to test out of introductory courses, dissatisfaction with the lack of available support from TAs or ULAs, and strong dissatisfaction with the quality of teaching. Of particular note were comments by several respondents who reporting feeling that introductory courses were structured to encourage attrition---to "weed out" potential STEM majors---and feeling that their instructors did not have an encouraging mindset, as well as overly competitive classmates. These comments were similar to the general comments on why they dropped the major as a whole, showing that there are systemic factors that not only prevent students from staying in the major, but also actively push students away from the major starting as early as freshman year.

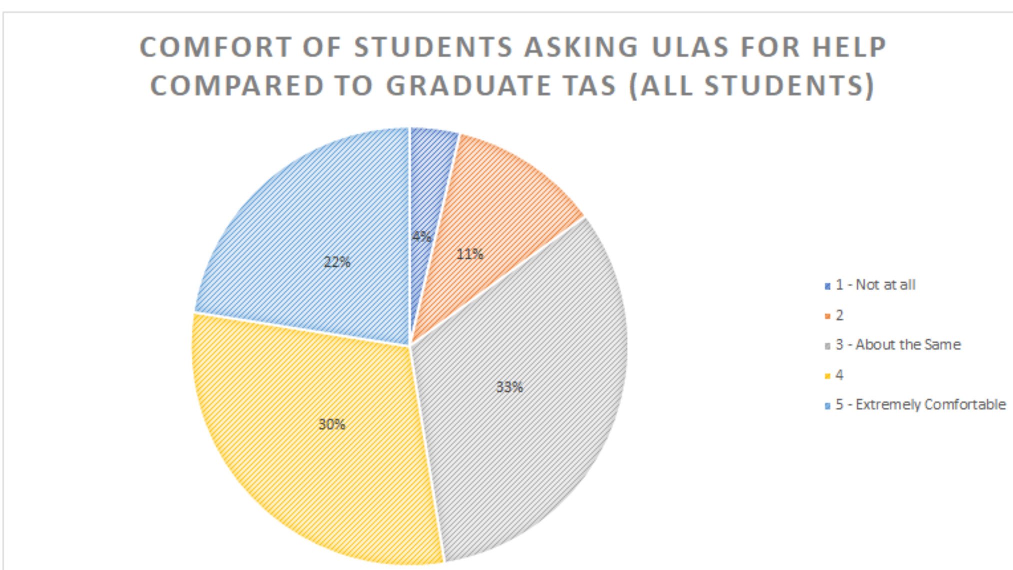
Success of undergraduate learning assistants

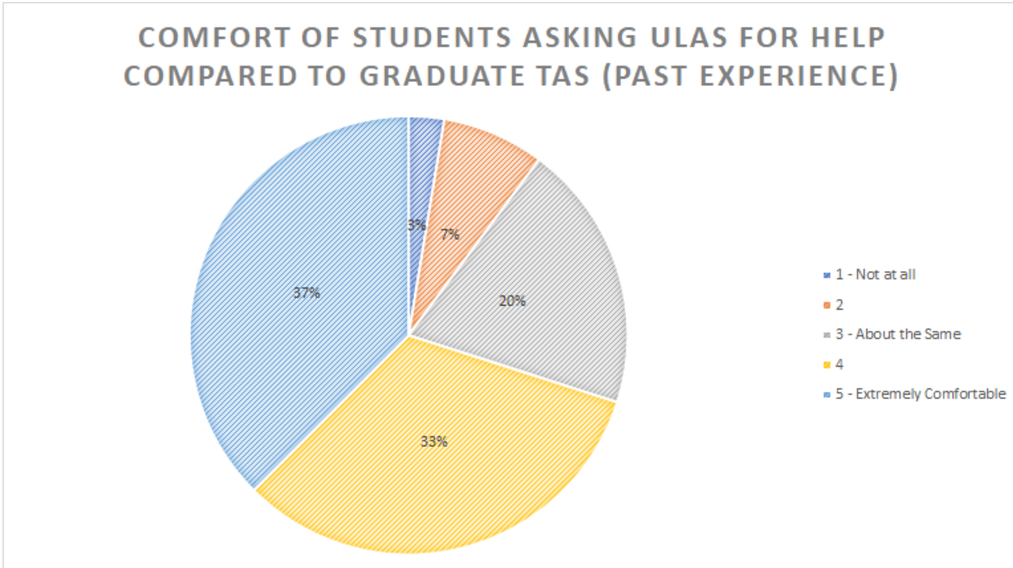
Each year, more STEM departments employ undergraduate learning assistants (ULAs), who hold office hours and grade assignments, as either an addition or an alternative to graduate student teaching fellows. This program was initiated by the computer science department in the fall of 2015 with the introduction of CPSC100 (CS50) from Harvard, which has used ULAs successfully for a number of their larger courses in computer science, economics, and statistics, and has subsequently been partnered with the Center for Teaching and Learning (CTL). In the introductory computer science courses (CPSC 100 and CPSC 112), ULAs hold section, while in upper-level computer science courses, ULAs hold weekly office hours. In the math department, ULAs are a more recent addition; lower-level courses (through the mid 300s) generally have a single peer tutor each with weekly office hours.

Comfort of students with ULAs

Getting feedback from students on the usage of ULAs in their learning experiences is critical. We collected both student feedback on comfort of using ULAs compared to graduate TAs, as well as whether the student had used a ULA in a past course. Our results show that having taken at least one course in which ULAs were used shifted student sentiment of ULAs (comfort asking ULAs for help) up by almost half a point, while also reducing the variances of numeric responses.

For the entire population of students, the average comfort of using an undergraduate learning assistant compared to a graduate teaching assistant was relatively high, with a mean of 3.56 on a 5-point Likert scale. However, this comfort increased by 0.4 if the student had already had experience working with a ULA, reporting a mean comfort level of 3.95. The distribution of the student ratings also changed, with a significant shift away from a score of 3 (about the same level of comfort with ULAs as graduate TAs) towards 4 and 5. This shows that students can become more accustomed to working with ULAs and may prefer working with ULAs through this experience. Overall, experience of students with ULAs seems to be positive in general.





Of the 691 students surveyed who have used ULAs in previous courses, the median comfort of using ULAs was 4 on a scale of 1 to 5, from least to most comfortable, and the average was 3.95. The median comfort of using ULAs compared to graduate TAs was also high (4 on a scale of 1 to 5), indicating that the majority of students are more comfortable being helped by an undergraduate peer than by a graduate student.

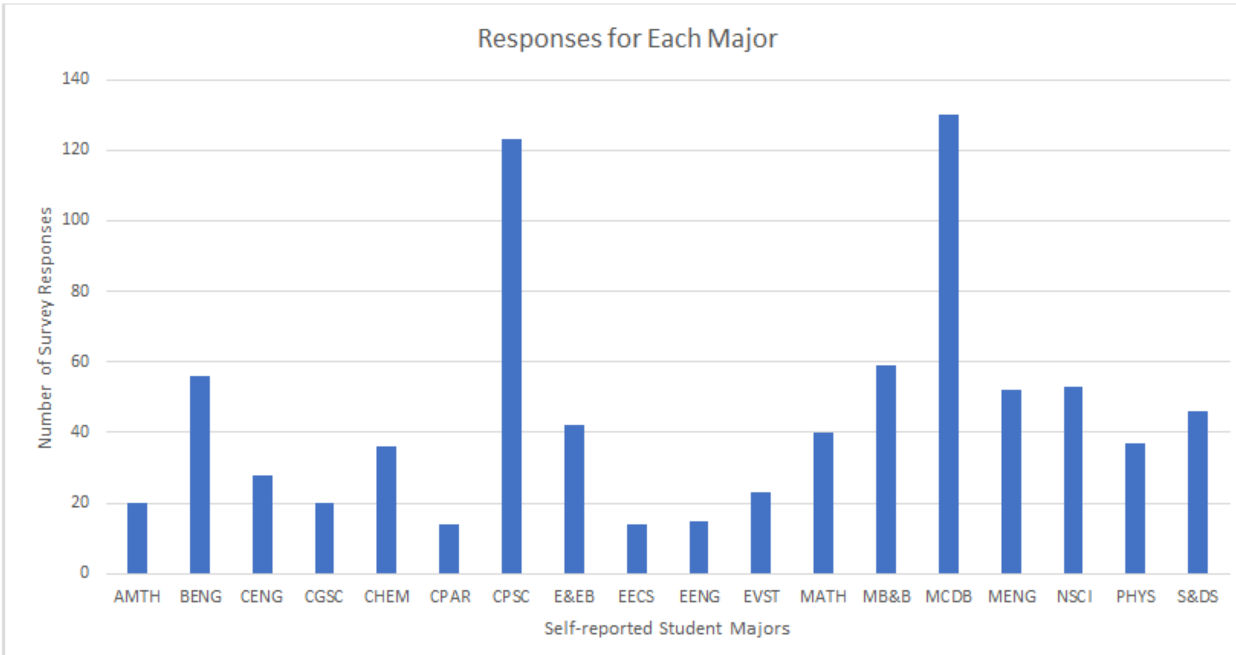
Comments on improving the usage of ULAs

Of the 253 students who commented on ULAs, 158 of the comments asked for more ULAs. Another theme centered on the improvement of ULAs, including comments that asked for "better training" and "better assistance." Lastly, students commented about wanting "more diverse hours" and "better help hour times." Given the positive feedback that students gave on ULAs, the expansion of ULA usage across introductory classes or large lectures in STEM departments should continue. In particular, an increase in funding for ULAs would enable additional hiring, satisfying the common request for more ULAs. As for improving the students' experience with using ULAs, streamlining hiring practices across different classes and departments could help ensure that the hired ULAs are familiar with the class material and demonstrate an interest in teaching and learning how to teach, while streamlining ULA training can improve the teaching styles of ULAs.

Student evaluations of STEM majors

Statistics of STEM major data

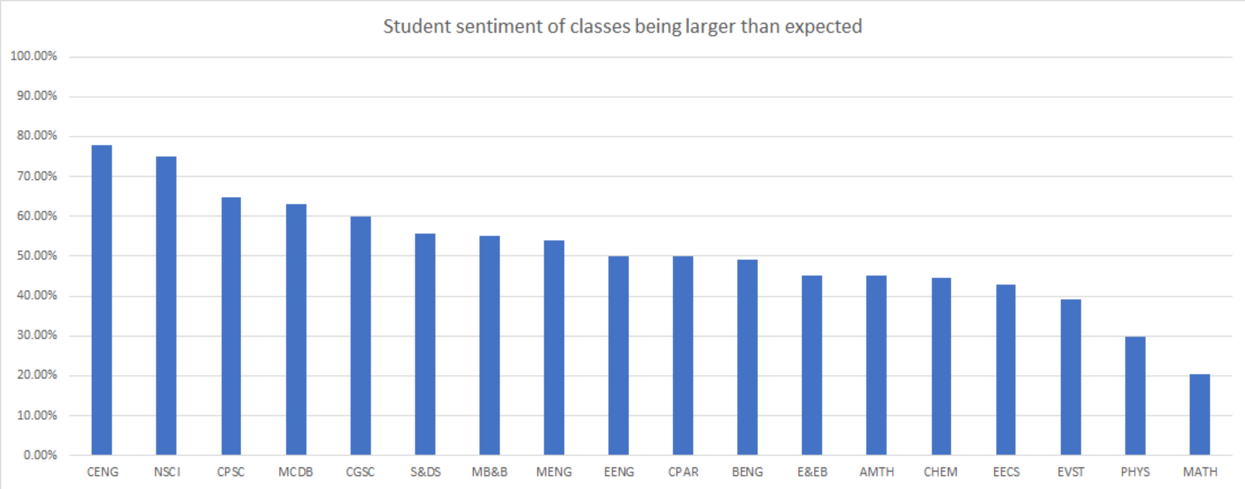
With 1192 students identifying as being in a STEM major responding to the YCC survey, we collected some general metrics on how majors were doing, including student sentiment of current class sizes and departmental support of undergraduates. Double-major responses were discounted for not clearly distinguishing which major was discussed when answering the survey. Five majors, biology, applied physics, astrophysics, environmental engineering, and geology & geophysics, were ignored because fewer than 10 students for each major responded. Furthermore, psychology and economics responses were struck, as both disciplines fall under social science instead of science and the only people who responded for these majors were those who incorrectly classified these as STEM majors. Ultimately, 808 responses of majors were analyzed in this section.



For the remaining 18 majors, our data seems to be representative of each major. We compared response ratios of each major to the number of total survey responses to the graduation data from the Class of 2016, and found that almost all ratios were the within half a percent difference. This remaining discrepancy can likely be explained as natural changes to the student body over the course of 2 years, the introduction of the cognitive science, neuroscience, and S&DS majors, and polling errors.

Sentiment on STEM class sizes

As a whole, 46.1% of STEM students felt that required classes for their major were larger than expected. The departments that felt their class sizes were largest were the chemical engineering major (77.8% yes, n = 28), the neuroscience major (75% yes, n = 53), the computer science major (64.75% yes, n = 123), and the MCDB major (63.08% yes, n = 130). On the flip side, the majors with most satisfaction in class size were the math major (20.51% yes, n = 40), the physics major (29.73% yes, n = 37), the environmental studies major (39.13% yes, n = 23) and the EE/CS major (42.86% yes, n = 14).



Overall satisfaction of individual STEM majors

We also polled students on their satisfaction with their department in six different areas: support of major students, responsiveness to undergraduate input, departmental events, encouragement of undergraduate research, diversity in faculty members, and selection of extracurriculars. On the whole, reviews were positive; averages across all STEM departments on all questions were above a 3 (average). In addition, across all STEM departments, the responsiveness of departments to undergraduate feedback rated the best (3.705 average) while the selection of electives rated the worst (3.403 average).

There was wide variation between the disciplines for each individual question, with no single statement being a clear predictor of other questions. In particular, there was very little tracking between expected class size and other responses on the survey.

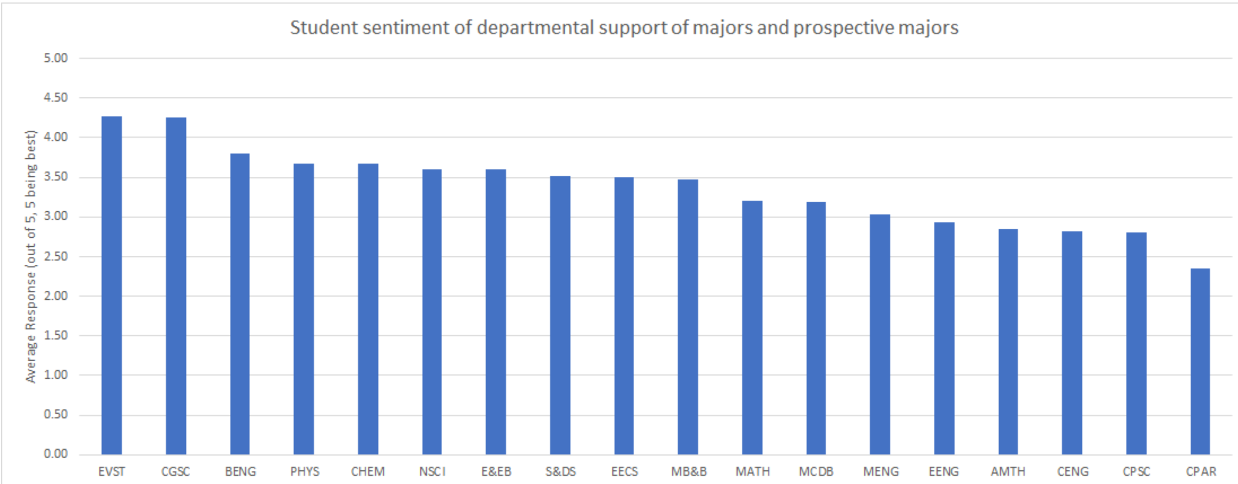
As a whole, engineering and computer science majors were the most critical of their departments. Computing and the arts, in particular, ranked their department the lowest of the 18 departments surveyed on five of the six questions asked, with especially low scores in departmental support of undergraduate research (1.82 average) and departmental support of students (2.36 average). In addition, computer science students ranked their department very poorly on departmental support of students (2.81 average) and on selection of electives (2.71 average).

On the other hand, two of the newly created majors, cognitive science and neuroscience, were both ranked very highly. Students in cognitive science ranked their major the best in terms of responsiveness to undergraduate input (4.85 average) and students in neuroscience ranked their major the best in recruiting diverse faculty members (4.39 average).

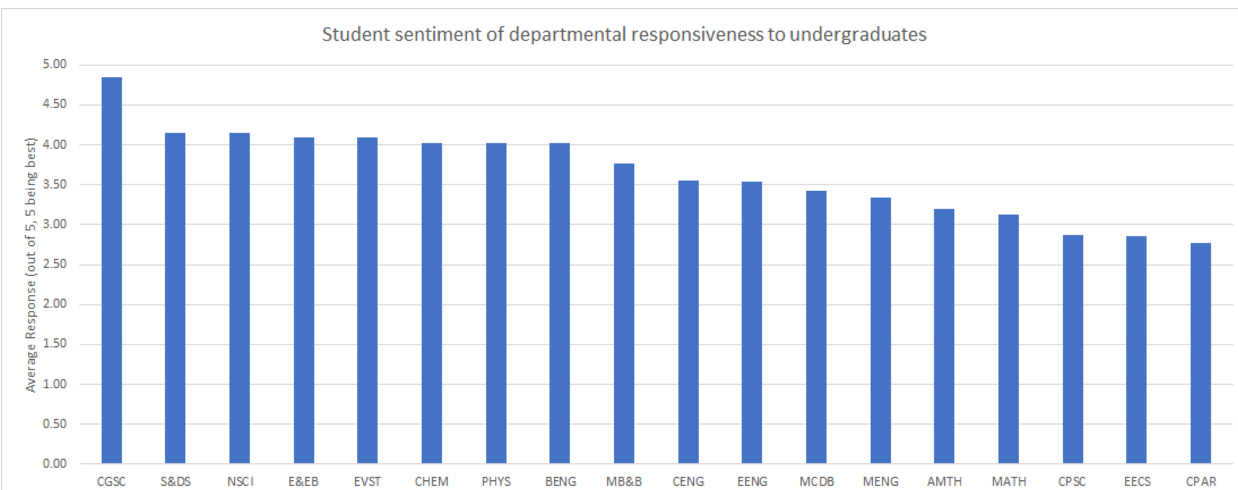
Whether these survey results point to a pressing need for reform in any particular department is unclear at best. However, the data supports the students' desire for more electives being offered within STEM departments, especially in the larger biology, engineering, and computer science majors.

Breakdown of student sentiment towards STEM majors on individual topics

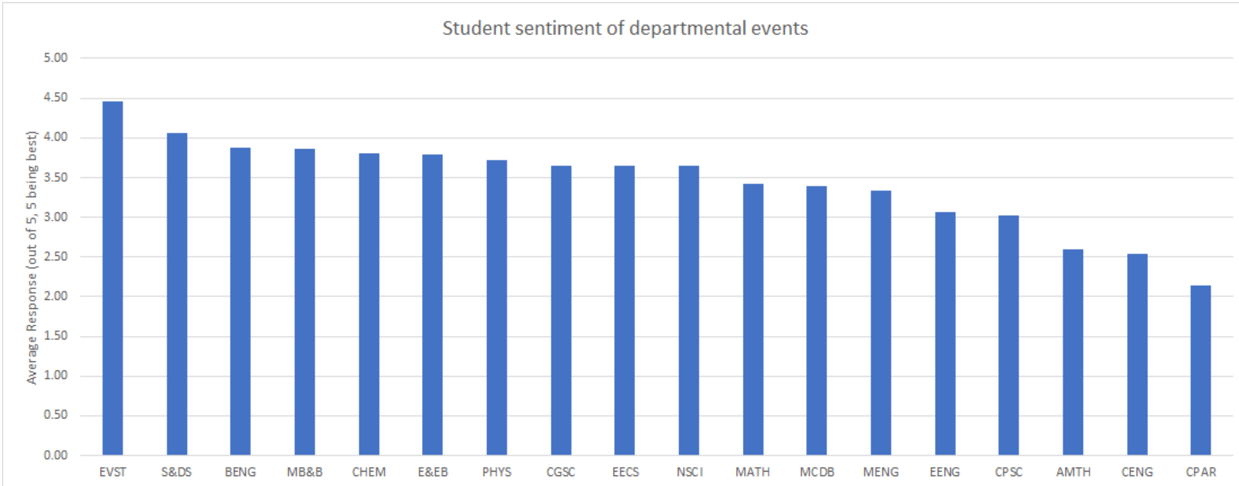
Overall, most students believed that their STEM department was supportive of them during their undergraduate studies, with strong showings in the environmental studies, physics, chemistry, and biology majors. However, there was a noticeable drop-off in this sentiment when it came to computer science, electrical and mechanical engineering, and applied math departments.



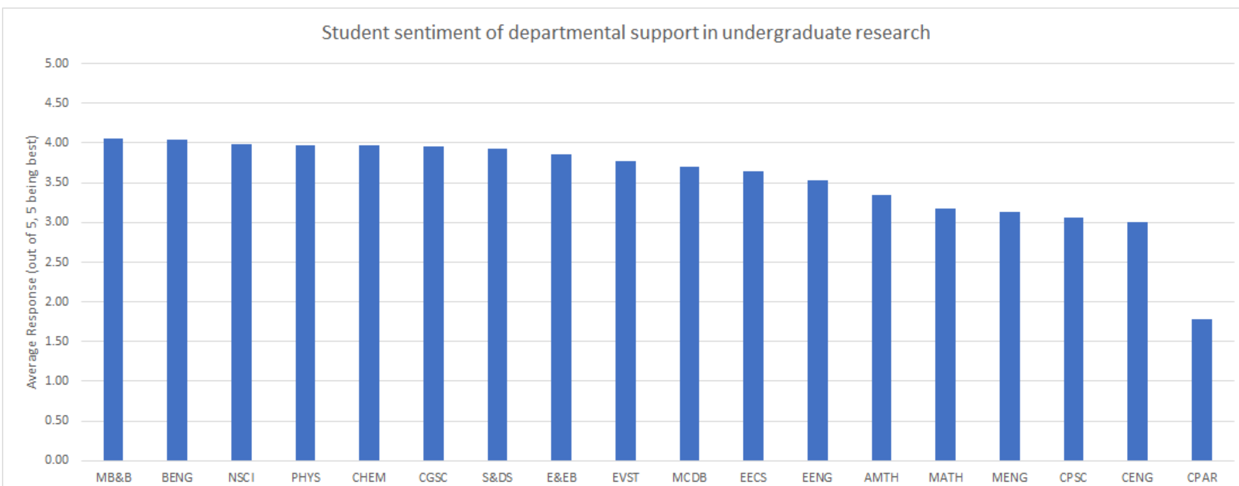
The same division appears in the sentiment towards department responsiveness to undergraduate students. While the average seems higher for responsiveness than for overall support, the grouping of engineering, math, and computer science undergraduates reporting dissatisfaction is significant.



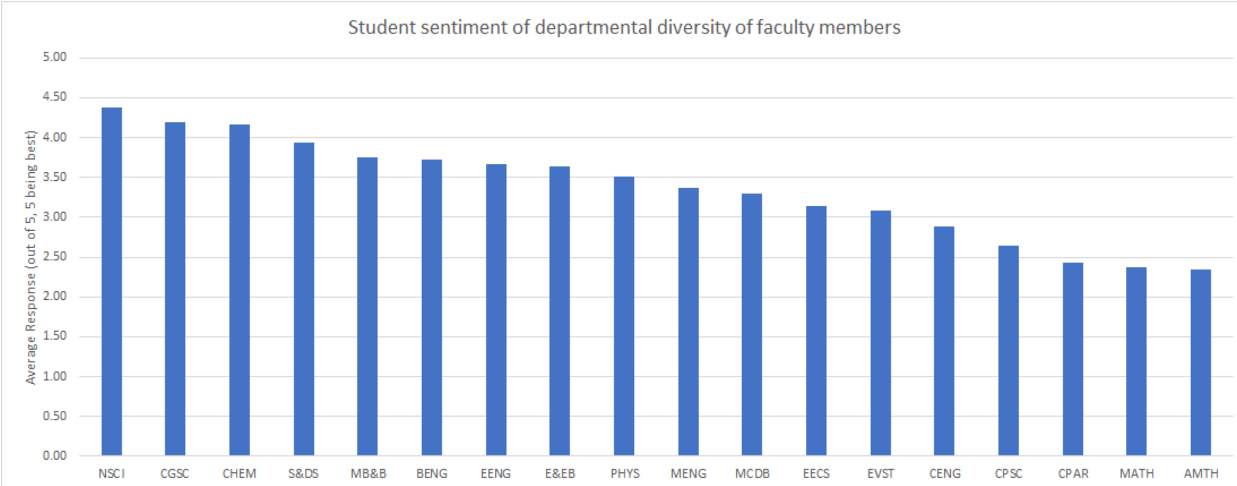
In general, most Yale undergraduates were pleased with the number of events that were hosted by the department. This does not come as a surprise, as all of Yale's STEM departments have strong core research faculty with many departmental colloquiums and invited speakers in general. Applied math, chemical engineering, and computing and the arts are the primary outliers on this topic.

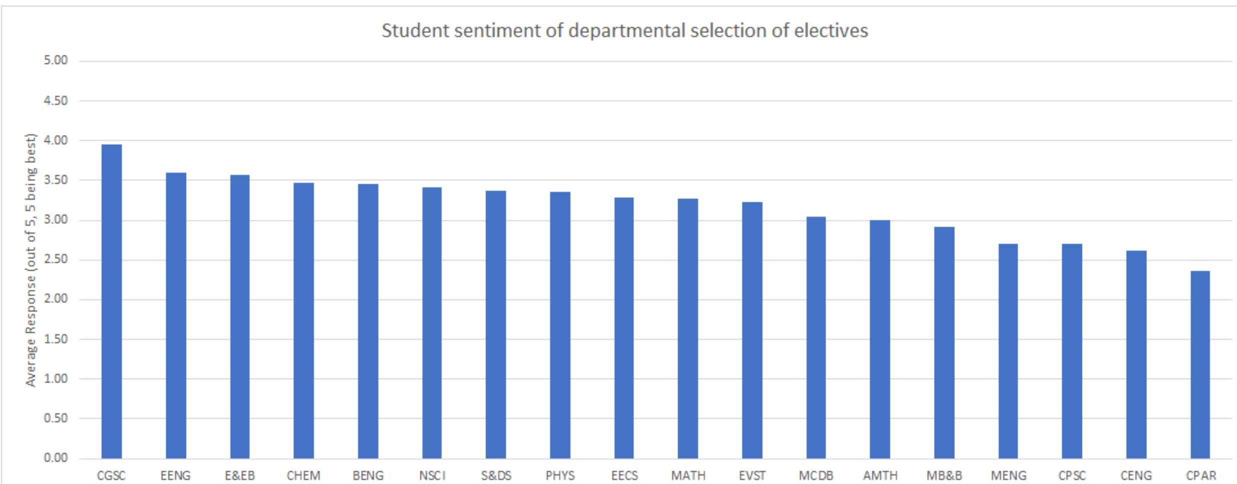


There is relatively little variation in the student sentiment on departmental support of research. This likely points to a strong culture of research-oriented projects throughout all of the STEM departments, with both faculty mentorship in research projects as well as institutional systems to promote senior and summer research work.



Regarding the diversity in faculty members, no department received an average 5/5 rating; both math and applied math were ranked the lowest, with averages below 2.5, followed closely by both computer science and computing and the arts, with averages near 2.5 as well. This sends a clear message; increasing faculty diversity seems to be the most urgent in mathematics and computer science faculty, and must be prioritized at both a departmental and college-wide level.





Of the comments students provided about their departments, the most common one throughout all of the responses was the desire for more elective courses and smaller class sizes. One student in the biomedical engineering major specifically requested for "professors who are better equipped to teach required lecture courses", while several students in the math department specifically were seeking more diverse faculty. There are other comments, including one from a student in the MB&B department seeking "more flexibility with pre-requisites and cross-listed electives' and one from a student in the physics department for "more clarity on offerings". Despite promising results in an earlier section regarding departmental research, several comments also requested "more research opportunities," and "better, more interesting research and sharing those opportunities with students so we can consider them early on."

These results are useful in guiding departmental policy on what students feel are most lacking in their departments, and can be used to prioritize different college-wide undergraduate initiatives, such as ULA training or introductory course structures. While specific, targeted improvements likely must be undertaken by individual departments in consultation with their students and faculty members, e.g. through departmental student advisory committees, we hope that this data can be passed along to help STEM directors of undergraduate studies find ways to improve the undergraduate experience.

Future outlook of the committee

The data that our committee has collected over the past semester is multifaceted and correlated with many different components of the university's priorities in providing a world-class education. Through the YCC survey, we have collected statistically significant samples of student sentiment on a broad range of issues that departments and administrators are interested in. Our analysis and recommendations will hopefully be helpful for department administrators in terms of choosing priorities and directions for the upcoming year. In the future, we hope to continue asking some of the same questions, in order to collect longitudinal data and to hopefully see the effect of new projects initiated by the students, professors, and administrators of Yale College.

Drafters and signatories of the report

In support whereof, we hereunto set our hands:

Chunyang Ding
Hannah Lawrence
Keshav Raghavan
Julia Wei
Jacob Zavatone-Veth
Anushree Agrawal
Annie Chen
Malak Khan

dated: 18 February 2019