STEM Resources and Courses
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BACKGROUND

In 2019, the new Yale Science Building officially opened its doors; its many exciting features include the Marsh Lecture Hall, the first classroom at Yale that can seat the entirety of an introductory chemistry course. The completion of the Yale Science Building was a testament to the University’s commitment to funding STEM education. In this time of greater attention being paid to STEM fields, the Yale College Council Academics Team has set out to research existing barriers facing STEM students and ways to best suit Yale’s resources to students’ needs and challenges.

We recognize that students intending to study STEM at Yale come from all levels of preparation and exposure to university-level science, which can lead to disparate experiences in both introductory and advanced courses. In this report, we investigate potential avenues through which students who are overwhelmed by or underprepared for intensive STEM courses can access preparation, guidance, and assistance. Through research, conversations with administrators, and a student focus group, we have determined the most feasible and effective methods for creating equity for students from all backgrounds interested in STEM. We recommend the establishment of an enrichment program for General Chemistry, modeled after the existing enrichment program for the BIOL 101-104 sequence, and the provision of additional resources for particularly challenging courses such as General Chemistry lab.
RESEARCH FINDINGS

Peer institution research
Many peer institutions have some sort of enrichment programs, especially for First-Years, that Yale completely lacks. Harvard University has the Harvard College Emerging Scholars Program, an academic enrichment program for STEM students currently enrolled in introductory calculus. This program offers a weekly seminar led by the mathematics department faculty to solidify concepts and delve into a deeper sense of understanding for these concepts, personalized academic advising and support, and even preparation for summer research and study. A majority of the colleges in the Ivy League have a similar program for high school or college students.

SHPEP (Summer Health Professions Education Program) is offered in 12 schools. Each institution provides instructions for basic concepts in science and math at the college level, as well as learning and study skills seminars, clinical and career development activities, and financial planning workshops.

UC Berkeley’s “Freshman Edge” takes place in two, eight-week sessions. The purpose is to get incoming First-Years more acclimated to the college environment while forming connections with peers and faculty so that the transition is not as steep. Summer session staff are available in the residence halls for drop-in advising sessions to provide support and help in the transition from high school to college. Financial aid is available for this program.

Existing Programs
An enrichment program already exists for the introductory Biology sequence. The program is voluntary, and students are granted a space in the oversubscribed program based on need. The purpose of this enrichment program is to fill gaps in students’ confidence and understanding in this specific course.

Fall Survey findings
On our annual fall semester survey of the student body, the YCC asked about students’ opinions of enrichment programs as a method to increase their success in these classes. Over 1,300 students reported having taken an introductory-level STEM class, of which just over 50% (647 students) had taken a class that offered an enrichment learning section. Of students that had taken an introductory-level STEM course at Yale which had not offered an optional enrichment program, two thirds of students agreed that an enrichment section would have “helped [their] learning” (see graph below). The fact that an overwhelming majority of students believe an enrichment section would improve their learning indicates that there is a demand for enrichment sections in classes that do not currently offer them, and that these sections would support the success of students in introductory STEM classes.
Focus group findings
We conducted a focus group of students in STEM fields who had concerning experiences with the high expectations of their courses. Our findings are summarized below.

Although students are aware of the existence of various “currently-existing” resources designed to provide support to those enrolled in STEM courses, the lack of coordination between these resources often makes them difficult to utilize effectively. One student argued that STEM majors are “thrown to the wolves” upon arriving at Yale, as very little guidance is provided regarding the available resources and how to use them. This atmosphere may discourage students from pursuing studies in STEM fields. The following sections explore the reasons for this phenomenon in greater detail.

Workloads and Credit Allotment
Students acknowledged the high workload of STEM courses (relative to courses in the humanities) but were generally skeptical that workloads could be reduced without compromising student learning or cutting out essential parts of the curriculum. This high workload may be attributable to the general structure of STEM courses, in which students are typically assigned weekly or bi-weekly problem sets. This structure stands in contrast to that of non-STEM classes, in which students are usually assigned essays or short response papers on a less frequent basis. Reducing the number of problem sets assigned over the course of a semester, however, may lead to gaps in understanding; in fact, one student reported difficulty recalling concepts from classes with fewer problem sets.

For these reasons, it would likely be more productive to improve the resources available to STEM students enrolled in difficult courses than to directly reduce the workload of these courses. One particularly helpful resource is peer tutoring, since students who have already taken a certain course can provide advice about both the content of the course and the test-taking and study strategies that have proven to be most effective. Similarly, in our focus group, students expressed satisfaction with programs that allow them to seek advice from older students in their major, whether formally or informally.

Although it may not be feasible to directly reduce the workloads of upper-level STEM courses, the same is not necessarily true for introductory courses, such as CS50. Students often take these courses to become more broadly familiar with a field or to obtain skills, such as basic computer programming, that are useful for a variety of careers. In this case, it may be possible to reduce workloads by placing emphasis on the acquisition of skills, rather than the development of specific knowledge, without putting students at a disadvantage. However, most introductory STEM courses already have fairly manageable workloads as is, so this type of change might be limited in its effectiveness.

Introductory Courses
Although none of the students in our focus group participated in the introductory biology enrichment program, they reported hearing positive things about its effectiveness. The presence of a dedicated course coordinator capable of providing additional support to students outside of class is one of the factors that makes this enrichment program especially helpful, especially because many students enrolled in introductory biology have not yet declared a major and therefore do not have access to departmental advising resources.

The introductory physics sequence does not have an accompanying enrichment program, but it is designed to accommodate students entering Yale with different levels of exposure to physics. Students may choose to take PHYS 170/171, 180/181, 200/201, or 260/261; this tiered course structure “acknowledges different start points” while still sufficiently preparing students for upper-level courses in their respective majors. Moreover, each course sequence is tailored for students with different interests; for example, pre-med students generally choose to take PHYS 170/171 (University Physics for the Life Sciences), while students intending to pursue higher studies in physics are more likely to take PHYS 260/261 (Intensive Introductory Physics). The chemistry department similarly offers three levels of introductory courses: CHEM 161/165, CHEM 163/167, and CHEM 174/175, although the latter (organic chemistry) can be taken only upon successful completion of a placement test. Although the existence of multiple introductory courses is helpful in certain ways, there is one major downside: each department offers only one introductory lab sequence, and the concepts taught in the lab course do not necessarily align with the subject matter of the corresponding introductory course. One student reported that the curriculum of PHYS 165La, the first semester of introductory physics lab, was consistent with the material covered in PHYS 180, while that of PHYS 166Lb corresponded more closely to the material covered in PHYS 170. Discrepancies between coursework and lab work may prove frustrating for students enrolled in both courses concurrently.

Students reported that while the Statistics and Data Science (S&DS) and Computer Science (CS) departments also offer multiple introductory courses, the student demographic towards which each course is targeted is often unclear. According to a student in our focus group, S&DS in particular “has a lot of entry points, but the purpose of each entry point isn’t defined.” The ongoing development of various S&DS courses (such as S&DS 240 and 355) that only require a background in MATH 115, rather than MATH 120, may increase the confusion that students face as they attempt to select the most appropriate classes for their intended program of study. Further clarification of the expectations and intended purpose of each introductory-level course would be helpful.

Yearlong introductory course sequences benefit from the presence of a dedicated teaching professor whose research commitments are sufficiently low to permit high engagement with students. Having the same TA/TF for both semesters of the course may also be helpful, as it facilitates the development of closer mentorship relationships between students and teaching staff and makes students feel more comfortable seeking help.
Enrichment programs may be less necessary for courses that already offer a robust variety of resources, such as frequent office hours and peer tutoring. (One example of such a course is PHYS 180).

Lab Courses
One course that we believe would benefit from the addition of an enrichment program is CHEM 134L/136L (General Chemistry Laboratory I and II). According to students, this is their “first real chemistry class,” since high school chemistry is often not reflective of the level of rigor of college chemistry. Additionally, students are expected to have a basic understanding of how to perform data analysis using applications such as Microsoft Excel, but not all high schools teach this. For those without the requisite data analysis experience, lab reports can be frustrating and time-consuming. Since these skills are not directly relevant to the course material, it may also be difficult to seek help from the teaching staff, so students are often left struggling on their own. It is important to note that these enrichment courses would also be oversubscribed due to limitations on resources, so it is important that new enrichment programs also admit students based on need.

Students also differ in their level of familiarity with a lab setting. Some, especially those enrolled in CHEM 174/175 and 220L/221L (Organic Chemistry for First Year Students I and II and the corresponding lab courses), have conducted independent research before coming to Yale, and as such are comfortable in the lab; others, however, may be setting foot in a college-level chemistry lab for the first time in these courses. Students in this latter group may struggle to manage their time well during lab, since the experimental process is expedited considerably by prior experience with lab equipment. Long hours spent in lab, the intimidation of being surrounded by unfamiliar apparatuses and people who seem to know exactly what they’re doing, and the frustration of having to learn how to operate data analysis software on one’s own time can all contribute to feelings of impostor syndrome and a general disillusionment with STEM education. An enrichment program dedicated to increasing students’ familiarity with the lab environment and teaching crucial data analysis skills would help ameliorate this situation.
RECOMMENDATIONS

We recommend the establishment of enrichment programs for the most popular introductory STEM courses for which such a program does not already exist. A good initial target for this kind of program would be CHEM 134L/136L (General Chemistry Laboratory I and II), as discussed above.

Because some of the skills necessary for success in this course, such as familiarity with Microsoft Excel or even with just a laboratory setting, are neither directly tied to the curriculum nor taught in class, these courses could create helpful optional enrichment sessions held outside of class hours for students who feel that they would benefit from extra instruction. These sessions would not necessarily need to be held throughout the entire yearlong course sequence; instead, they could be offered in a few installments at the beginning of each semester (in order to accommodate those who begin the sequence in the spring). This format would be appealing to students because it would require a lower time commitment than programs such as BIOL 101–104 Enrichment I and II, which are offered on a weekly basis. However, we understand that the biology enrichment programs have been successful, and if adequate resources exist, we recommend that CHEM enrichment programs also follow the same structure as biology enrichment programs.

We have also identified a need for content-based enrichment sections, like those currently offered in the introductory biology sequence.
FINAL THOUGHTS

We hope that we have provided clear guidelines and future steps to expand STEM resources and provide more support for those who feel underprepared for introductory level classes at Yale. This initiative would particularly benefit students who identify as first generation and/or low income students, who face barriers to engaging in Yale’s course offerings due to being underprepared or having a lack of access to information. Expanding resources is necessary for making STEM fields more equitable and welcoming to all students interested in pursuing studies at Yale. Should there be any questions, concerns, or other thoughts, please do not hesitate to contact us at mia.haraguchi@yale.edu, reilly.johnson@yale.edu, yasmin.abdella@yale.edu, sam.woo@yale.edu, or sarah.pitafi@yale.edu.