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Design of novel courses to bridge knowledge gaps in engineering and reduce attrition and graduation delays

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Introduction

Nationally and internationally, engineering programs experience more attrition and longer times to graduate than other majors. Yorke and Longeden [1] document this from a public policy standpoint at various universities in the United States, United Kingdom, Australia, and South Africa. Long et al. [2] and [3] opine that the main reasons for student attrition include:

- Poor preparation for higher education;
- Weak institutional and/or course match which results in poor fit and lack of commitment;
- Unsatisfactory academic experience;
- Lack of social integration;
- Financial issues and personal circumstances; and
- Wrong initial course selection and movement to other courses that meet their interests and aspirations more directly.

To understand student attrition rates better and guide educational quality improvement, [4] recommend separate consideration of the teaching and learning perspectives aspects of student retention. They, and [5] [6], and [7] also observe the importance of early and enhanced student engagement. Astin [8] and [9] define student engagement as a student's academic commitment and application which is shown in the time and energy devoted by the student to activities that are educationally purposeful, in addition to the quality of the effort and their understanding.

Brysen and Hand [10] suggest that engagement be fostered by student-centered conceptual orientation as opposed to faculty-centered content orientation in teaching. To promote such early student engagement, [4] emphasize the value of immersive student-responsive curricula that integrate appropriate induction and study skills, and content and tasks that are challenging and relevant to the students' futures. They also highlight the importance of formative assessment to obtain early, immediate and relevant information regarding students' academic development needs. Tanner [11] proposes the use of metacognition to help students learn to learn.

In addition to these student-responsive curricular developments, [12] recommend the inclusion of disciplinary concepts at an early stage for academic survival, retention and success. They advocate that classrooms should include active and interactive learning in order to help students develop an understanding of core disciplinary concepts.

The current study builds upon these recommendations for student-centered curricula that are introduced at the early stage of the program, and that actively engage students to develop ability and commitment.

Research Design and Methodology

This research hypothesizes that negative impacts such as attrition and delays in graduation, even among students who have a strong desire to become engineers, may be explained by an inability to overcome specific social challenges common to engineering students, and can be redressed by the introduction of novel preparatory courses to bridge knowledge gaps, instill helpful skills and habits, and better position students for success. The research design involves four elements intended to occur during 2020-2028. This paper reports on the completed first two elements of the study.

With the exception of the "challenges survey" in Fall 2021 and the longitudinal analysis of transcripts, all of the other assessments are slightly modified versions of existing voluntary and anonymous surveys that are used every semester as part of the program's existing continuous improvement process.

Element 1. Develop, conduct, and analyze results of "challenges" survey

This survey asks students to share information about their academic preparation from high school to college, and their performance in prerequisite math and science courses and sophomore level engineering courses. The survey also asks them to share their attitudes regarding the importance of prerequisite courses to success in later courses; their willingness to adapt study habits to meet the demands of the major; their understanding of the curriculum and ability to select electives of the greatest interest to them without causing a delay; and the value of participation in beneficial extracurricular activities such as professional organizations, professional development, research and internships.

For its intended purpose to inform the initial development of the preparatory courses, it is not critical that all current students participate in this survey as we expect that the courses will be refined over their first few offerings to reflect the needs of the greater student population. Our minimum target response rate is 25%.

Two primary research questions are to be investigated using the results of this survey.

1. How do the attitudes/behaviors of sophomores differ from those of juniors and seniors?
    - Perceived importance of prerequisites
    - Study habits (independent and help-seeking)
    - Understanding of curriculum
    - Perceived importance of participation in extracurricular activities
2. How do the current attitudes/behaviors of sophomores, juniors, and seniors differ from their attitudes/behaviors before they began their engineering coursework?
    - Perceived importance of prerequisites
    - Study habits (independent and help-seeking)

Student responses are evaluated in two ways. First, they are summarized visually using graphs to show differences in student attitudes and behaviors based on their year in program and relative to their stated attitudes prior to beginning their engineering coursework.

Second, they are statistically analyzed using Fisher's Exact test of pairwise comparisons [13,14] to determine when the attitudes/behaviors reported by different groups of students are statistically significant. This test best suits our data due to its limited sample size and the 2 by 2 contingency nature of the student responses (e.g., important vs. not important). The Fisher's Exact test-statistic follows a hypergeometric distribution when the null hypothesis H_0 is true. Assuming that the number of successes is fixed across the two groups, we reject H_0: $p_1 = p_2$ for the alternate hypothesis H_A: $p_1 > p_2$ if there are more successes in group 1 compared to group 2.

The p-value is derived under the assumption that the number of successes in the first group has a hypergeometric distribution when H_0 is true. Smaller p-values indicate that the null hypothesis H_0 is less likely and therefore provides strong evidence of the alternate hypothesis H_A. that the proportion of sophomores who state in the affirmative that they have a particular attitude/behavior, is equal to the proportion of juniors (or seniors) who state the same. The alternate hypothesis is that the proportion of juniors (or seniors) who state this, is greater than that of the sophomores who state the same. To evaluate Research Question 2, we establish a null hypothesis that the proportion of current sophomores, juniors, and seniors who state in the affirmative that they have a particular attitude/behavior, is equal to the proportion of the same students who state the same about themselves at a time before they had begun their engineering courses.

Element 2. Develop preparatory courses and assessment tools

In this element, we design the preparatory course and its assessment tools. As a starting point for the course design, we refer to the literature. To reduce attrition, the literature highlights the benefit of student-responsive courses offered early in the curriculum, that use enhanced active and interactive engagement, and that address a wide range of topics such as induction, information about the disciplines, study skills, and challenging and relevant content. These topics are broad, and can be divided into professional knowledge and technical knowledge. As a starting point, we therefore assume that we will require a professionalism course and a technical course. The "challenges" survey feedback is used to further embellish the two courses.

This element also involves the design of end of course assessment tools. End of course surveys are administered in every engineering course in the final class period. The questions on these surveys include self-assessment of attainment of course learning objectives and relevant ABET-EAC student outcomes.

Element 3. Conduct end of course surveys in preparatory courses to refine courses

Each of the two preparatory courses will be assessed twice in the Fall 2021-Spring 2023 period using end of course surveys. These assessments will be used to assess student learning and to refine the design and implementation of the preparatory courses in their first couple offerings.

Given the intended purpose of these surveys to refine the courses to best meet the needs of the students, our target minimum response rate on these surveys is 75%.

Element 4. Conduct longitudinal study of graduates

Three cohorts of students will be studied to numerically assess the effectiveness of the two preparatory courses. Each cohort will contain 80-100 unique students based on historical enrollments in the program. Like many other engineering programs, our program is designed to be completed in four years but many students take longer to graduate. As a result, the cohorts are defined based on when the student took the preparatory course but assessed four to six years later upon graduation.

The three cohorts are:

- Cohort 1 - Students not taking either preparatory course in 2020-2021 (estimated graduation in 2024-2026);

- Cohort 2 - Students who took the professional preparatory course in 2021-2022 (estimated graduation in 2025-2027); and
- Cohort 3 - Students who took both preparatory courses in 2022-2023 (estimated graduation in 2026-2028).

These cohorts will be studied using two assessment tools. The first assessment tool is the blinded transcripts of all of the students in the three cohorts. Each student's transcript will be statistically analyzed to quantify the differences between cohorts of performance in sophomore-level civil engineering courses, time to select specialization, time to graduate, and the rate of attrition from the program. The second assessment tool is the graduating senior survey which is administered in the culminating senior design course in the final week of class every semester. The questions on this survey are typically limited to self-assessment of their experience in the program and college and attainment of the ABET-EAC student outcomes. For the purposes of this research, this survey will be modified to gather numerical data about their non-academic experiences (i.e., those not captured on a transcript). The graduating senior surveys of all students in the three cohorts will be statistically analyzed to quantify the differences between cohorts in their participation in non-academic activities and the impact of the preparatory courses on their passion, drive and morale.

Given the intended purpose of the longitudinal study, our target minimum response rate for the graduating senior survey is 75%. The transcript analysis will involve 100% of the students in each of the cohorts, including students who elected to leave the major.

Results of Research Element 1

The anonymous and voluntary challenges survey **(Appendix A)** was developed and circulated to all students in the civil engineering program in Fall 2021. 102 students (35% of 289 enrolled students) chose to participate. 13 participants were removed from the analysis because they had not taken any engineering courses. Of the remaining participants, there are similar numbers of sophomores (33), juniors (23) and seniors (33). For the purposes of the analyses that follow, we consider two cohorts of students on the basis of their likelihood of completing the program: the 33 sophomores who have not yet advanced past the Mechanics of Deformable Bodies (CE 332) course, and the 56 juniors and seniors who have. Students who pass this course are most likely to remain in the program.

The participants entered the program with diverse preparation. 25% of participants attended high schools that specialized in math, science or engineering, and 47% of participants received AP credit for calculus and/or physics. 57% of the participants entered into the program as freshmen, with the remaining transferring into the program from other engineering majors or non-engineering majors (28%), or as second-degree students (15%). These statistics highlight the diversity in background and perspective with which students enter engineering programs.

<u>Performance in Coursework</u>

Figure 1 illustrates the performance of all participants in the math, physics, computing, and english courses typically taken as freshmen, as well as in the engineering courses that follow these prerequisites (which all of the juniors and seniors have completed but only 8 of the surveyed sophomores have completed).

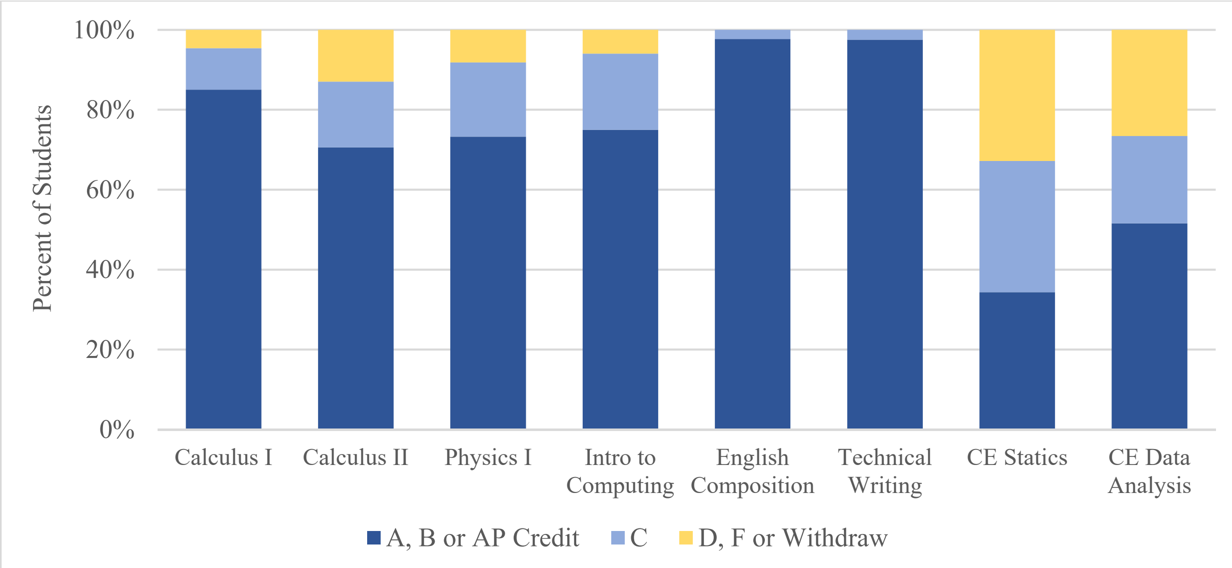

Figure 1. Performance in Prerequisite Subjects as Freshmen (n=89) and in Statics and Data Analysis as Sophomores (n=64)

On the whole, students do fairly well in the prerequisite subjects, but their performance drops off considerably in entry level engineering courses. A substantial number of participants received a failing grade in their sophomore level engineering courses. We posit that this decline in performance is due to difficulty in applying theory to practice, difficulty in developing critical thinking skills and robust study skills, and a lack of connection to the discipline and future profession.

Although it is difficult to draw definite conclusions given the sample size, **Table 1** suggests that students who earned A or B grades in prerequisite courses, or received AP credit for the courses, performed better in Statics than those passing the prerequisites with a C, and vica versa. A similar but weaker relationship is observed for Data Analysis. In our program, a passing grade in these courses is a C. Students who receive a D may not advance and must repeat the course.

Table 1. Relationship Between Performance in Prerequisite Courses and Performance in Sophomore-Level Statics and Data Analysis

Prerequisite Course and Performance	**Calculus I**			**Calculus II**			**Physics I**		
	A or B, or AP Credit	**C**	**D or F**	**A or B, or AP Credit**	**C**	**D or F**	**A or B, or AP Credit**	**C**	**D or F**
Performance in Statics (CE 231)									
Total Students	**54**	**7**	**2**	**43**	**10**	**9**	**48**	**12**	**4**
% Advancing	76%	57%	50%	77%	80%	44%	81%	58%	25%
% Not advancing	24%	43%	50%	23%	20%	56%	19%	42%	75%
Performance in Data Analysis (CE 264)									
Total Students	**55**	**6**	**2**	**44**	**9**	**9**	**48**	**12**	**4**
% Advancing	73%	33%	0%	75%	67%	22%	79%	33%	25%
% Not advancing	27%	67%	100%	25%	33%	78%	21%	67%	75%

Perceived Importance of Prerequisites
Student perceptions of the importance of prerequisites change as they advance through the civil engineering curriculum.

Figure 2 presents the perceptions of all survey participants based on their class standing.

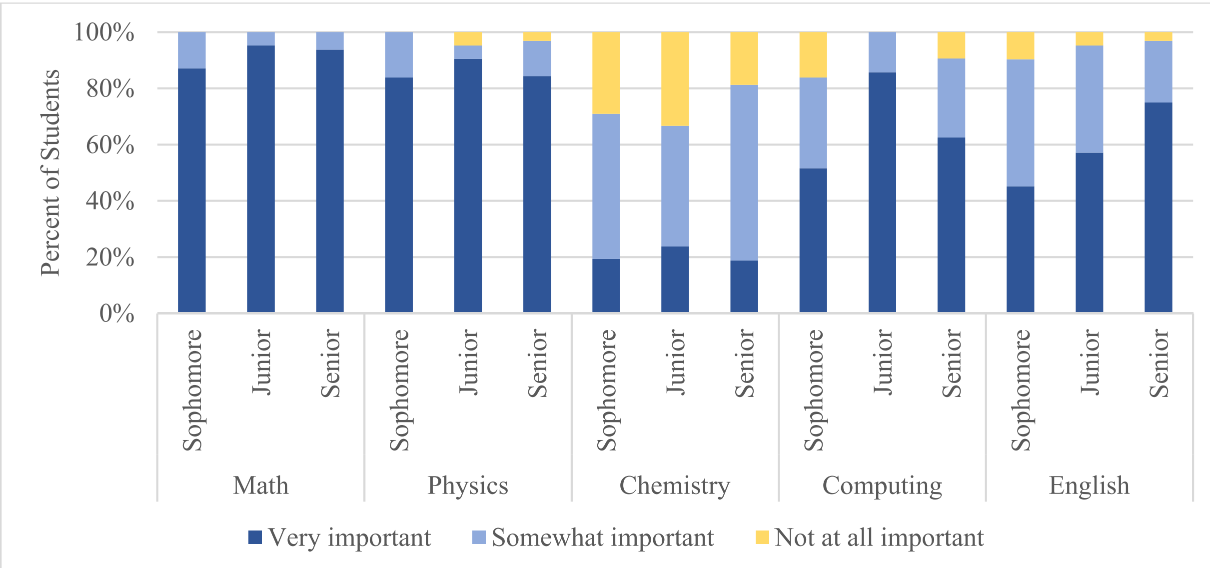

Figure 2. Perceived Importance of Prerequisites
by Current Sophomores (n=31), Juniors (n=21) and Seniors (n=32)

A very high share of students in all cohorts appreciate the relevance of math and physics to civil engineering, an unsurprising result given the relevance of these topics to highly visible applications of civil engineering such as building and bridge design. It appears that the recognized importance of chemistry, computing, and english grow over time as students apply these subjects to civil engineering problems in their coursework. However, with this limited sample, only the increased recognition of the importance of computing for juniors compared to sophomores is statistically significant (**Appendix E, Table E-1**).

Figure 3 compares students' current perceptions of the importance of prerequisites to their stated perceptions before they began engineering coursework, and reinforces the results of the prior analysis.

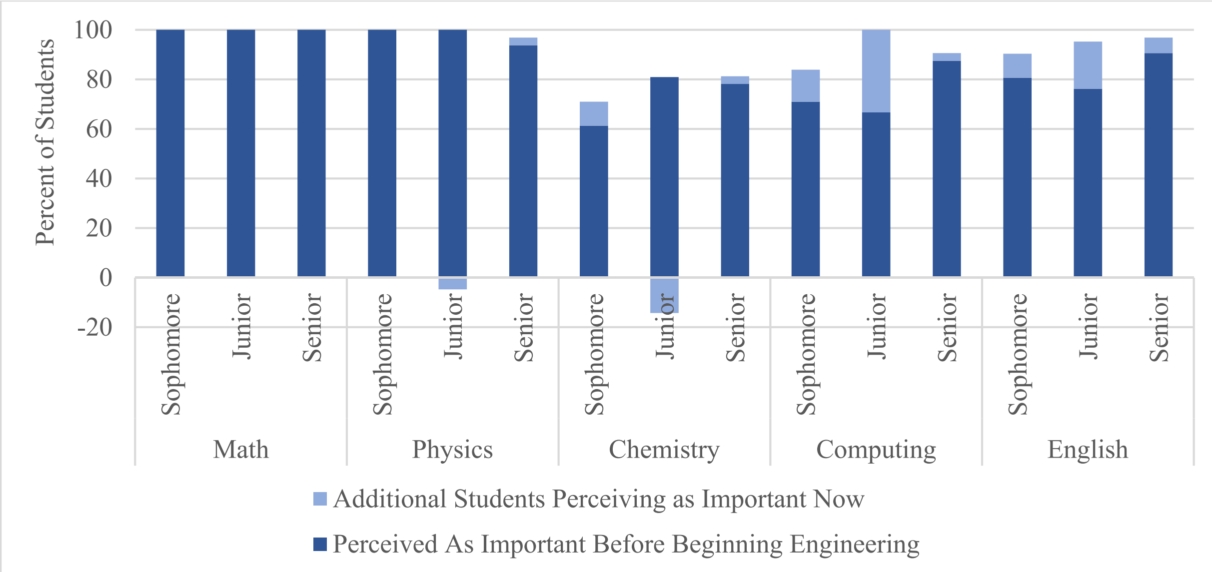

Figure 3. Change in Perceived Importance of Prerequisites by Current Sophomores (n=31), Juniors (n=21) and Seniors (n=32) vs. Themselves Prior to Beginning Engineering Coursework

Here, growth is also observed in the recognized importance of computing and english for all groups over time. For juniors, the higher share of student that recognize the importance of computing and english is statistically significant (**Appendix E, Table E-2**). The lower level of recognition of the importance of computing and english may explain the poorer performance in the sophomore-level data analysis course which requires computing and reading comprehension.

These results highlight the need to reinforce the relevance of these subjects early in a student's academic career.

Study Skills

Student study habits also change with academic standing. **Figure 4** presents the shares of current sophomores, juniors, and seniors who use specific methods for independent study.

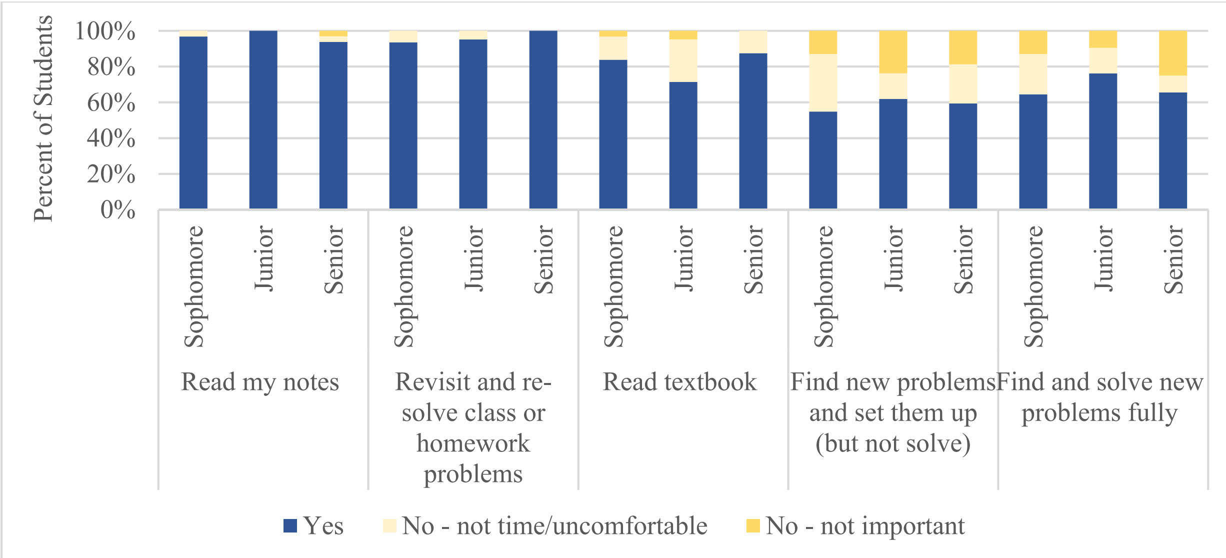

Figure 4. Comparison of Independent Study Habits in Current Sophomores (n=31), Juniors (n=21) and Seniors (n=32)

It is clear that students at all levels (including prior to engineering) employ basic practices such as reviewing their notes and re-solving problems already solved in class or on the homework, although a small share of sophomores and juniors indicate that they do not have time for or are not comfortable doing these basics.

Figure 5 demonstrates how these students' current study habits compare to their habits prior to beginning their engineering coursework.

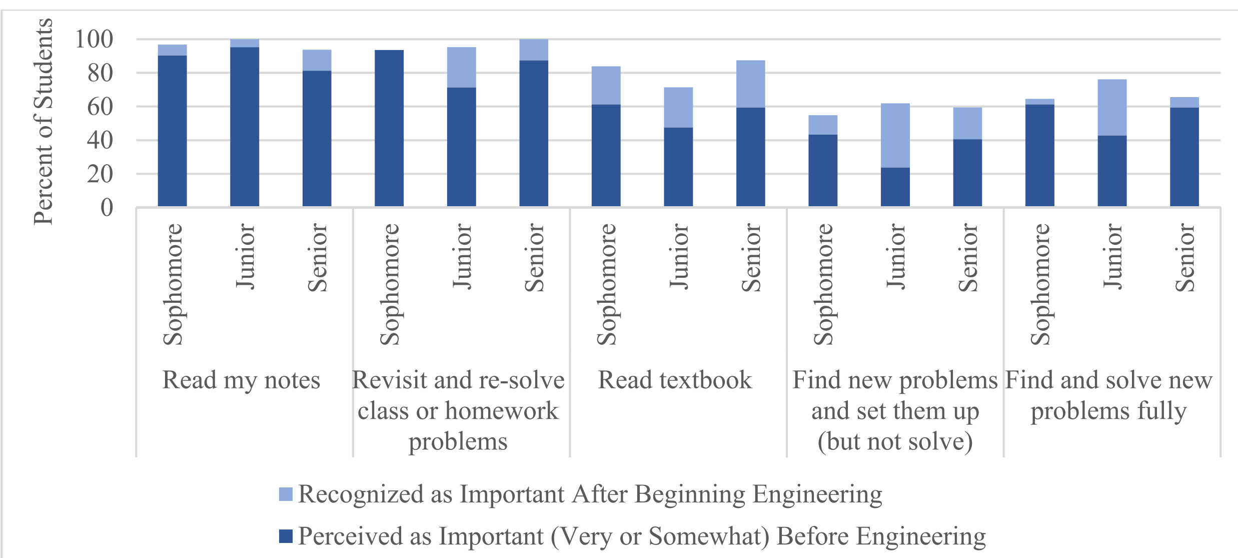

Figure 5. Changes in Use of Independent Study Methods Before and After Beginning Engineering Coursework for Current Sophomores (n=31), Juniors (n=21) and Seniors (n=32)

This figure also makes clear that students at all levels (including prior to engineering) employ basic practices such as reviewing their notes and re-solving problems already solved in class or on the homework, although a small share of sophomores and juniors indicate that they do not have time for or are not comfortable doing these basics. Students are much more likely to read their textbooks after entering engineering, a result confirmed by Fisher's Exact test results (**Appendix E, Table E2**). Although no significant differences between cohorts are observed in seeking out additional problems to either set up or solve completely, current students appear more likely to use this method now than prior to before they began their engineering coursework. For juniors, this difference is statistically significant (**Appendix E, Table E2**). Notably, the share of sophomores seeking, setting up, and solving new problems is higher than expected. This may be due to their limited access to instructors, TAs, and classmates while completing pre-engineering courses during the COVID-19 pandemic.

Figure 6 presents the shares of current student cohorts seeking help via various methods.

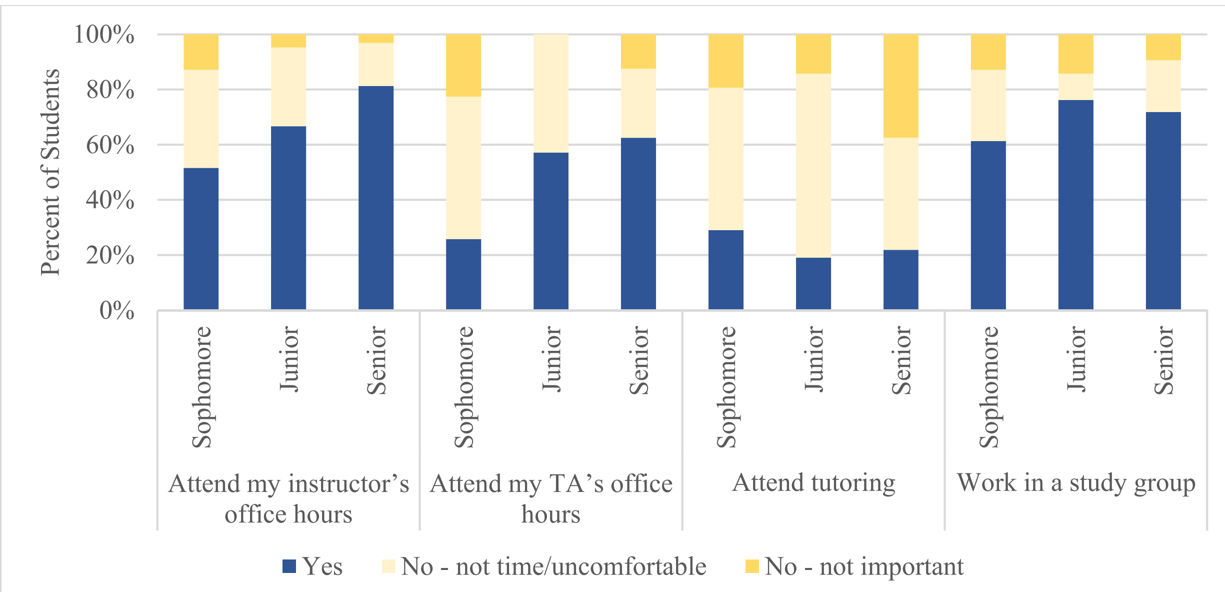

Figure 6. Comparison of Help-Seeking Study Habits in Current Sophomores (n=31), Juniors (n=21) and Seniors (n=32)

Overall, fewer students seek help from outside resources than use independent study methods. As students progress through the program, the share who visit faculty and instructor office hours and work in groups increases. The higher shares are significant for seniors (both instructor and TA) and juniors (TA only) (**Appendix E, Table E1**). Many sophomores in particular cite lack of time or comfort as a reason not to attend instructor or TA office hours. Overall, few students seek tutoring. Use of tutoring is higher among sophomores than other cohorts; this is consistent with the practice at our college to provide tutoring primarily for sophomore-level courses.

Figure 7 demonstrates how these students' current help-seeking compares to their habits prior to beginning their engineering coursework.

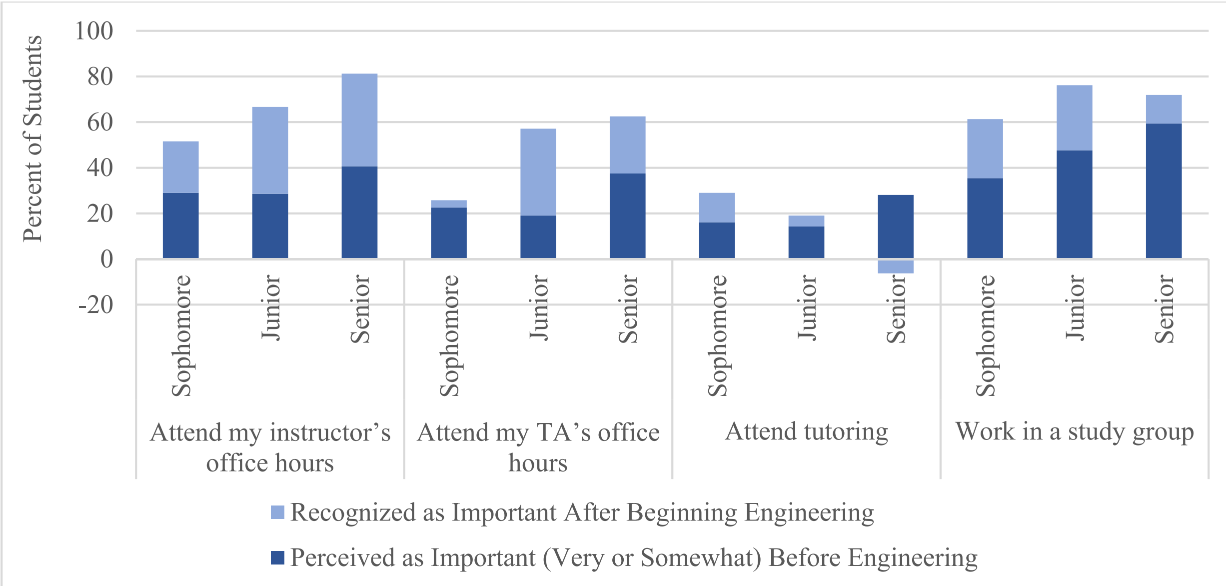

Figure 7. Changes in Use of Help-Seeking Study Methods Before and After Beginning Engineering Coursework for Current Sophomores (n=31), Juniors (n=21) and Seniors (n=32)

First, it is clear that help-seeking of all types increases after students enter engineering. Significant increases are observed in attendance at instructor office hours (all three cohorts), attendance at TA office hours (juniors and seniors), and working in groups (sophomores and juniors) (**Appendix E, Table E2**). Interestingly, here it is also clear that the senior cohort includes higher shares of students who recognized the importance of help-seeking – including visiting office hours, working in groups, and pursuing tutoring prior to entering engineering. This may have been a positive factor in student retention for this cohort.

Overall, seniors show a greater amount of adaptation of study habits than sophomores who have only taken one or two engineering courses. The seniors reported that the process of adaptation was triggered by the difficulty in the course material, and the increased expectations of the instructors. Some reported that they hesitated to adapt at first, and that the process of adaptation spanned two to six semesters. Approximately 60% of the seniors adapted by seeking out problems other than the ones solved in class and on their homework, attending their instructor's and teaching assistant's office hours or seeking out tutoring. A little over 40% of the seniors adapted by muddling through the new problems they found and studying with their peers. Anecdotally, students also reported excessive number of hours studying outside of the classroom.

These issues highlight the need to assist students in the development of robust and efficient study skills early in their academic career.

<u>Understanding of Curriculum</u>

A solid understanding of the curriculum lays the groundwork for fewer delays in graduation and better planning when it comes to selecting a specialization and elective courses. **Figure 8** details the level of understanding of various aspects of the curriculum for sophomores, juniors and seniors.

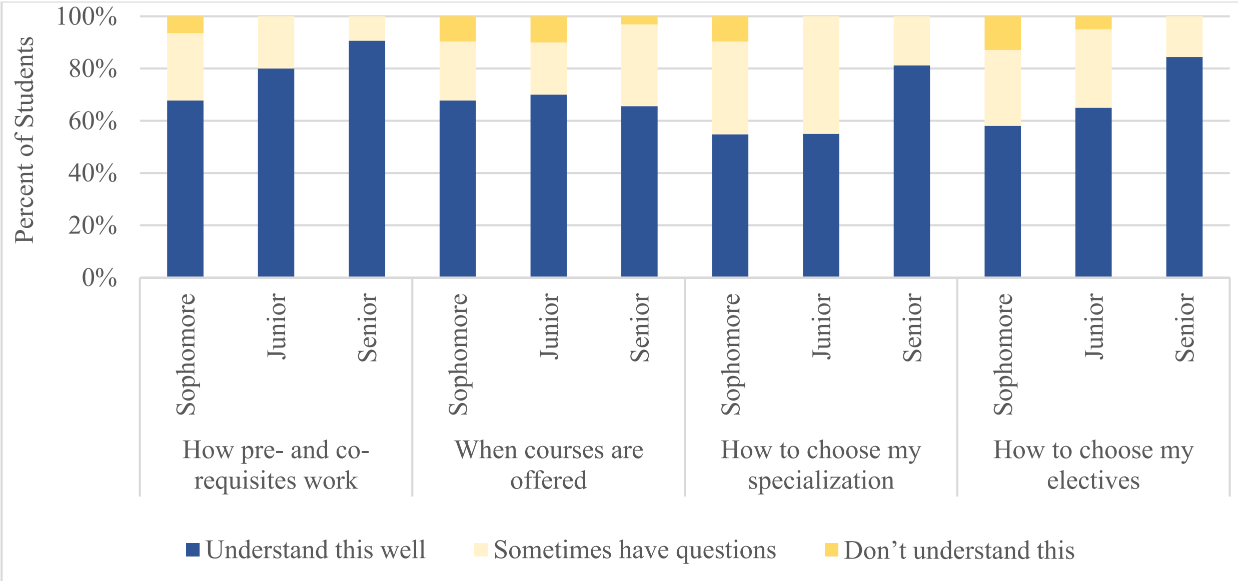

Figure 8. Understanding of Curriculum by Current Sophomores (n=31), Juniors (n=21) and Seniors (n=32)

Compared to sophomores, a significantly higher share of seniors state that they understand how pre- and corequisites work and how to select a specialization and electives (**Appendix E, Table E1**). This result is consistent with expected knowledge gained with longer experience in the program.

The discrepancy between the two academic groups and the fact that some seniors lack an understanding of the curriculum highlights the need to develop in students a greater understanding early on in their academic careers.

<u>Importance of Valuable Extracurricular Activities</u>

Valuable extracurricular activities help connect students to the profession. Common activities include attending seminars given by practicing engineers, participating in professional organizations, taking advantage of professional development opportunities on campus, doing internships, participating in research with a practicing engineer, and starting the process of getting licensed.

Figure 9 shows the perceived importance of these activities among sophomores, juniors and seniors.

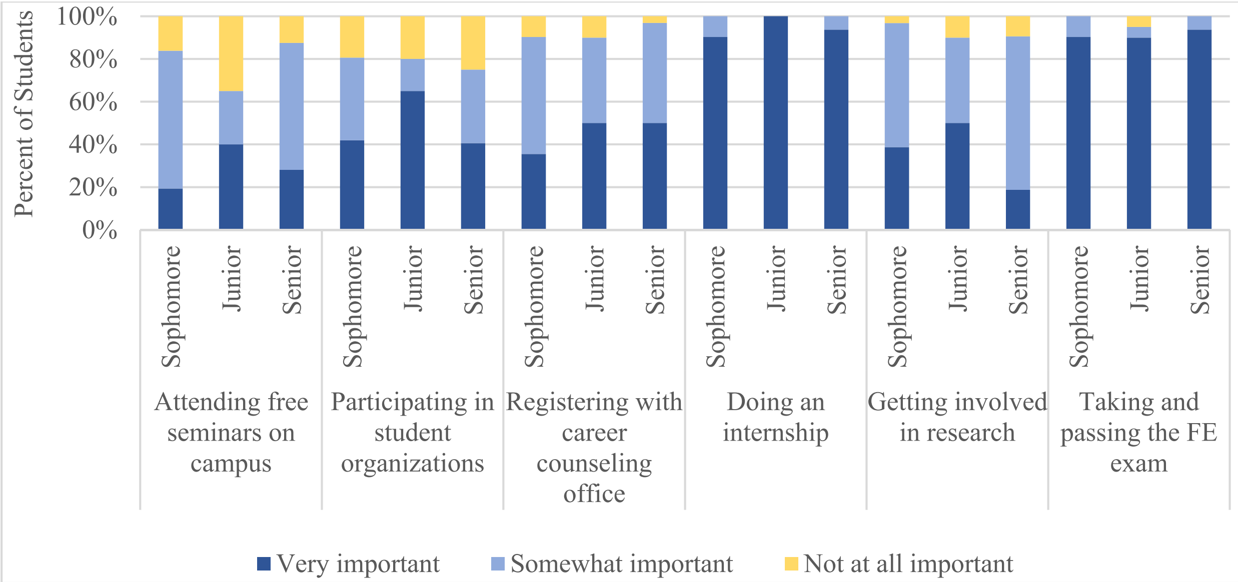

Figure 9. Comparison of Understanding of Importance of Valuable Extracurricular Activities by Current Sophomores (n=31), Juniors (n=21) and Seniors (n=32)

No significant differences in the share of students recognizing extracurricular activities as important are observed across cohorts (**Appendix E, Table E1**). Students at all levels value the activities that most resemble the practice: internships and licensure. Overall, they place lesser importance on seminars and research. Interestingly, they also do not value participation in professional organizations, or professional development (i.e., registering with CPDI), despite the networking or employment opportunities they provide.

These findings highlight the need to communicate the benefits of these activities at an early stage of their education.

Results of Research Element 2
Design of a professional preparation course and assessment tool
A number of challenges were identified that inform the content of a professional preparation course for sophomores. Students at this stage have a limited understanding of the relevance of english (written communications) and computing to the practice of Civil Engineering. Many do not recognize the value of participation in beneficial extracurricular activities which can stimulate interest and dedication. They also possess a limited understanding of civil engineering specializations and how to choose elective courses. This, combined with a general incomplete understanding of the curriculum and its constraints, can result in scheduling errors and poor choice of courses, which in turn can increase time to graduation.

The professional preparation course is designed to address these challenges. Given its non-technical nature, it is a 1-credit course. Given the need for time to interact with practicing engineers, it is a 3-contact hour course with a 50-minute lecture and a 110-minute lab/seminar period. The requisites to the course include successful completion of Physics I and current enrollment in Technical Writing, both of which are taken in the second semester of study. It is a corequisite to several 300 level courses, giving students two semesters in which to take this course. The course is taught by a single full-time faculty member once annually. The faculty conducts a majority of the lectures, and invites other full-time faculty as guests to talk about their specializations, as well as practicing engineers (primarily alumni) as guests to talk about their career paths and experiences.

The course employs active learning, and modular assessments such as developing a curriculum plan for completing the degree requirements, self-reflection, and basic problem sets to reinforce understanding of each specialization. Practicing professionals are invited to share their career paths and professional experiences.

The following topics are discussed in this course: 1. The Field of Civil Engineering: Career sectors and employment opportunities; expectations of the profession; the Civil Engineering Program at CCNY; policy objectives for civil engineering (public health and safety; sustainability; resiliency; financial responsibility; impacts, including consequences of failure); academic ethics; professional ethics; professional certifications; importance of written and oral communication. 2. Technical aspects of Civil Engineering: areas of specialization; fundamental design and critical thinking exercises to address Civil Engineering related problems.

Through these topics, the student will learn to: 1. Identify a broad range of career opportunities and areas of specialization within the field of civil engineering; 2. Recognize the expectations of the Civil Engineering profession, as outlined in the ASCE Code of Ethics; 3. Identify the steps required to earn licensure as a professional engineer and to become certified in a range of specializations within Civil Engineering; 4. Discuss the complex factors that are considered in and impacted by civil engineering practice, including public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors; 5. Develop a design to address a basic civil engineering problem given a set of constraints; 6. Apply critical thinking to develop a solution to a civil engineering problem to meet one or more specific objectives; and 7. Write a written report/provide an oral presentation.

The end of course assessment for this preparatory course includes self-assessments of level of attainment of key concepts before and after completing the course such as knowledge of the profession or the importance of ethics and communication (**Appendix B**). The graduating senior survey will be modified to also ask students to self-report if and when the student took the preparatory course, and the extent to which they registered with Career and Professional Development Institute (CPDI), and the number of semesters that they actively spent in internships, research and professional organizations (**Appendix C**).

Design of a technical preparation course and assessment tool

Student challenges that relate to a technical preparation course include: poor performance in sophomore engineering courses; limited appreciation of the importance of computing and reading comprehension (i.e., english) to engineering; and limited appreciation of the demands of engineering coursework, and willingness to adapt study habits to meet these demands. In addition to the challenges the students cited themselves, we theorize that poor performance in the sophomore engineering courses may also be explained by a limited ability to apply theoretically taught subjects like math and science to engineering problems; and limited recognition of the importance of critical thinking in problem solving or willingness to develop this ability.

The technical preparation course is designed to address these challenges. Given its emphasis on critical thinking and study and group skills, it is a 1-credit 1-contact hour course. In order to take the course, students must have successfully completed Physics I, Calculus II and Introduction to Computing, all of which are taken in the first or second semester of study. It is a prerequisite to the 300 level courses and so students must take this course alongside their 200 level civil engineering courses. To deliver the material in a more-timely manner to aid them in these 200 level courses, the course is conducted using two 50-minute lectures for the first half of the semester. This course is taught every semester by two full-time faculty members who rotate the responsibility. They deliver the lectures and invite senior level students to participate in the panel discussions.

The course employs active learning, and modular assessments that primarily involve self-reflection. Graduating seniors are invited to share their best practices for and lead discussions on the topics of study habits, student responsibility, and group work.

The following topics are discussed in this course: 1. Benefits of critical thinking and enhanced study skills and student responsibility for their education; 2. Metacognition for planning, monitoring and evaluating learning for the course overall, for class sessions, for homework, and for quizzes/exams; 3. Team member responsibilities, group meeting skills, clean communication approaches to give and receive feedback; 4. Review of relevant prerequisite topics (geometry, trigonometry, calculus, physics, and computer science) and application of concepts to simple civil engineering problems; 6. Critical thinking in problem solving with application to simple civil engineering problems; and 7. Present technical information clearly to others.

Through these topics, the student will learn to: 1. Develop study skills that improve student learning and make studying more time efficient; 2. Develop group work skills that allow groups to be more efficient and productive; 3. Be aware of their responsibilities as a student and prioritize their time to meet these responsibilities; 4. Apply theoretical concepts learned in prerequisite math and science courses to civil engineering problems; 5. Explain what critical thinking is and use it to solve problems that are unfamiliar; and 6. Demonstrate critical thinking in how problem solutions are written out to show clear understanding.

The end of course assessment for this preparatory course include self-assessments of level of attainment of key concepts before and after completing the course such as critical thinking and problem solving (**Appendix D**).

Conclusions

The aim of this eight-year study is to improve retention and reduce incidence of graduation delays in undergraduate engineering students, a national and international problem. The study design includes four elements: characterizing the challenges that contribute to attrition and graduation delays, development of two preparatory courses that address these challenges by bridging gaps in technical and professional knowledge, assessment of effectiveness of learning of specific topics in each course after each offering, and longitudinal assessment of effectiveness of reducing attrition and delays to graduation upon graduation.

The paper presents the completed findings for the first two elements. A few of the most notable challenges include poor performance in sophomore level courses, limited recognition of the importance of prerequisite topics such as english and computer science, delayed adaptation of study skills, and limited recognition of the importance of participating in meaningful extracurricular activities. Based on these findings, two preparatory courses were designed. The first course seeks to bridge the knowledge gap pertaining to the profession, thus stimulating students' interest in, and thus dedication to, their studies. The second course seeks to bridge the technical knowledge gap and improve students' ability and efficiency to learn, to think critically when solving problems, and to apply the theoretical concepts learned in the prerequisite courses to engineering applications.

Assessment tools are developed that facilitate a numerical statistical comparison of three cohorts of students upon graduation to learn of the effectiveness of the courses to reduce attrition and delays to graduation and enhance participation in valuable extra-curricular activities.

References

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APPENDIX A - Challenge Survey to all enrolled undergraduates in Fall 2021

CONSENT PAGE: This anonymous and voluntary survey is four pages and will take approximately 15 minutes to complete.

The survey is intended to help us understand the challenges that our students face. The results will be used to design/refine two new introductory courses in the CCNY civil engineering program intended to provide students with the support they need to be successful throughout the program. The new courses will replace existing requirements and so will not add any credits to the program. The results will be published in order to help other colleges address this same problem.

Thank you in advance for taking the time to help us evolve our program to better suit the needs of our students. To show our appreciation, you will have the option to enter a raffle for a CCNY GSOE sweatshirt in a separate link that is provided at the end of the survey. A separate link is used in order to protect your identity on this survey.

If you have any questions about this survey or your participation in it, please contact the chairperson of the department.

Participation in this survey is voluntary; refusal to participate will involve no penalty.

PAGE 1: The entire survey is four pages. Questions with an asterisk are required. This first page asks you about your preparation before coming to CCNY.

** 1. Did you attend a high school that specialized in math, science or engineering?*

- ○ Yes
- ○ No

2. If you completed any AP courses in high school, which ones? Select all that apply

- ☐ AP English Language and Composition
- ☐ AP English Literature and Composition
- ☐ AP Calculus AB
- ☐ AP Calculus BC
- ☐ AP Computer Science A
- ☐ AP Computer Science Principles
- ☐ AP Statistics
- ☐ AP Biology
- ☐ AP Chemistry
- ☐ AP Environmental Science
- ☐ AP Physics 1: Algebra-Based
- ☐ AP Physics 2: Algebra-Based
- ☐ AP Physics C: Electricity and Magnetism
- ☐ AP Physics C: Mechanics

** 3. How well did your high school studies prepare you for your college level courses? We recognize that you may not have completed all of these courses.*

	Very prepared	Somewhat prepared	Not at all prepared	I did not study this in high school
Math	○	○	○	○
Chemistry	○	○	○	○
Physics	○	○	○	○
Computing	○	○	○	○
English	○	○	○	○

4. Did you earn another degree before attending CCNY?

College and major for Associates degree ________________________

College and major for Bachelors degree ________________________

** 5. How did you enter the civil engineering program at CCNY?*

- ○ As a freshman
- ○ After completing prerequisite courses to be accepted into the School of Engineering
- ○ As a transfer student from another engineering major at CCNY
- ○ As a transfer student from a non-engineering major at CCNY
- ○ As a transfer student from another college besides CCNY

** 6. How did you do in these courses? (select all that apply)*

	Currently taking or not taken yet	A or B grade	C grade	D or F grade or withdraw	Got AP credit for this course	Took once	Took multiple times	Took at CCNY	Took at another college
Calculus I (Math 20100)	☐	☐	☐	☐	☐	☐	☐	☐	☐
Calculus II (Math 20200)	☐	☐	☐	☐	☐	☐	☐	☐	☐
Physics I (20700)	☐	☐	☐	☐	☐	☐	☐	☐	☐
Intro to computing (CSc 10200)	☐	☐	☐	☐	☐	☐	☐	☐	☐
English composition (English 10000)	☐	☐	☐	☐	☐	☐	☐	☐	☐
Technical writing (English 21007)	☐	☐	☐	☐	☐	☐	☐	☐	☐

** 7. How do you identify?*

- ○ Asian
- ○ Black
- ○ Hispanic
- ○ White
- ○ Prefer not to say
- ○ Other (please specify) ______________________

** 8. How do you identify?*

- ○ Female
- ○ Male
- ○ Prefer not to say
- ○ Other (please specify) ______________________

** 9. Are you the first person in your family to attend college?*

- ○ Yes
- ○ No
- ○ Prefer not to say

** 10. Do you work to support your studies?*

- ○ Yes, full-time
- ○ Yes, part-time
- ○ No
- ○ Prefer not to say

PAGE 2: This second page of the survey asks you about your how you are doing in college so far.

** 11. So we know where in the curriculum you are, which of these courses have you completed or are taking now?* (select all that apply)

- ☐ CE 231 Statics
- ☐ CE 332 Mechanics of Deformable Bodies
- ☐ CE 340 Structural Analysis
- ☐ CE 441 Reinforced Concrete
- ☐ CE 509 Senior Design Project

** 12. We replaced the ENGR 101 requirement with CE 101 a couple years ago. Which did you take?*

- ○ CE 101 Intro to Civil Engineering
- ○ ENGR 101 Intro to Engineering Design

- ○ Both ENGR 101 and CE 101
- ○ CE 51001 1-credit independent study to satisfy the ENGR 101 requirement
- ○ Neither – I haven't met this requirement yet

** 13. How well are you able to apply the topics you learned in these courses to your civil engineering courses?*

	All of the time	Some of the time	Seldom	I haven't taken any CE courses yet
Math	○	○	○	○
Chemistry	○	○	○	○
Physics	○	○	○	○
Computing	○	○	○	○
English	○	○	○	○

** 14. How did you do in these courses?* (select all that apply)

	Currently taking or not taken yet	A or B grade	C grade	D or F grade or withdraw	Took once	Took multiple times	Took at CCNY	Took at another college
CE 264 CE Data Analysis	☐	☐	☐	☐	☐	☐	☐	☐
CE 315 Computational Methods in CE	☐	☐	☐	☐	☐	☐	☐	☐
CE 316 CE Decisions and Systems Analysis	☐	☐	☐	☐	☐	☐	☐	☐
CE 231 Statics	☐	☐	☐	☐	☐	☐	☐	☐
CE 332 Mechanics of Deformable Bodies	☐	☐	☐	☐	☐	☐	☐	☐
CE 340 Structural Analysis	☐	☐	☐	☐	☐	☐	☐	☐

** 15. How many hours per week do/did you spend outside of the classroom doing assignments and studying for these civil engineering courses?* (if you didn't take it yet, please enter 0)

CE 264 CE Data Analysis ____________________
CE 315 Computational Methods ____________________
CE 316 CE Decisions & Systems Analysis ____________________
CE 231 Statics ____________________
CE 332 Mechanics of Deformable Bodies ____________________
CE 340 Structural Analysis ____________________

16. If you spend more time in some civil engineering courses than in others, why?

- ☐ The course was harder
- ☐ The course has more or longer assignments/tests
- ☐ Other (please specify ____________________

PAGE 3: Almost done! Please keep going. This third page of the survey asks you about your approach to studying engineering.

** 17. Before you started your CE coursework, how driven were you to earn a degree in civil engineering?*

- ○ A great deal
- ○ A lot
- ○ A moderate amount
- ○ A little
- ○ Not at all

** 18. Before you took any college-level engineering courses, how important did you think these topics were to civil engineering?*

	Very important	Somewhat important	Not at all important
Math	○	○	○
Chemistry	○	○	○
Physics	○	○	○
Computing	○	○	○
English	○	○	○

** 19. Now that you are taking civil engineering courses, how important do you think these topics are to civil engineering?*

	Very important	Somewhat important	Not at all important
Math	○	○	○
Chemistry	○	○	○
Physics	○	○	○
Computing	○	○	○
English	○	○	○

** 20. Before you took any of your civil engineering courses, how did you prepare for quizzes/tests in college?* (select all that apply)

	Yes	No because I didn't have the time	No because I didn't think it was important	No because I am not comfortable doing this
Read my notes	☐	☐	☐	☐
Read textbook	☐	☐	☐	☐
Revisit and re-solve class or homework problems	☐	☐	☐	☐
Find new problems and set them up (but not solve)	☐	☐	☐	☐
Find and solve new problems fully	☐	☐	☐	☐
Attend my instructor's office hours	☐	☐	☐	☐
Attend my TA's office hours	☐	☐	☐	☐
Attend tutoring through the Dean's office	☐	☐	☐	☐
Work in a study group	☐	☐	☐	☐

Other (please specify ________________________

** 21. If your way of preparing for quizzes/tests changed since you started taking civil engineering courses, how do you prepare for quizzes/tests for your engineering courses now? (select all that apply)*

	Same as before	Yes	No because I don't have the time	No because I don't think it is important	No because I am not comfortable doing this
Read my notes	☐	☐	☐	☐	☐
Read textbook	☐	☐	☐	☐	☐
Revisit and re-solve class or homework problems	☐	☐	☐	☐	☐

Find new problems and set them up (but not solve)	☐	☐	☐	☐	☐
Find and solve new problems fully	☐	☐	☐	☐	☐
Attend my instructor's office hours	☐	☐	☐	☐	☐
Attend my TA's office hours	☐	☐	☐	☐	☐
Attend tutoring through the Dean's office	☐	☐	☐	☐	☐
Work in a study group	☐	☐	☐	☐	☐

Other (please specify ________________________

22. If your way of preparing has changed, what caused you to change your approach and how long did it take for the change to happen?

** 23. Nowadays, do you feel confident that you are well prepared when you walk into an engineering quiz or test?*

- O Absolutely
- O Mostly
- O A little
- O No

24. If you need more support in order to do well in your civil engineering courses, please tell us what kind of support you need.

PAGE 4: This is the final page of the survey. On this page we ask you about your understanding of the curriculum and extracurricular activities.

** 25. Before you started your CE courses, how well did you understand these aspects of the CE curriculum?*

	I understood this really well	Sometimes I had questions	I didn't understand this at all
How pre- and corequisites work	O	O	O
When courses are offered	O	O	O
How to choose my specialization	O	O	O
How to choose my electives	O	O	O

** 26. Before you started your CE courses, how important did you consider participation in these extracurricular activities in college to be important to your career development?*

	Very important	Somewhat important	Not at all important
Attending free seminars on campus	O	O	O
Participating in student organizations	O	O	O
Registering with CPDI (Career and Professional Development Institute)	O	O	O
Doing an internship	O	O	O
Getting involved in research	O	O	O
Taking and passing the FE exam	O	O	O

** 27. Now how well do you understand these aspects of the CE curriculum?*

	I understand this really well	Sometimes I have questions	I don't understand this at all

How pre- and corequisites work	○	○	○
When courses are offered	○	○	○
How to choose my specialization	○	○	○
How to choose my electives	○	○	○

** 28. Do you consider participation in these extracurricular activities while you are in college to be important to your career development?*

	Very important	Somewhat important	Not at all important
Attending free seminars on campus	○	○	○
Participating in student organizations	○	○	○
Registering with CPDI (Career and Professional Development Institute)	○	○	○
Doing an internship	○	○	○
Getting involved in research	○	○	○
Taking and passing the FE exam	○	○	○

29. If you need more support around the curriculum and extracurricular activities, please tell us what kind of support you need.

EXIT PAGE: Thank you for completing this survey. We know it is long and so we really appreciate the time you spent filling it out.

RAFFLE FOR CCNY SCHOOL OF ENGINEERING SWEATSHIRT
To thank you for participating in the survey, we are giving away several GSOE sweatshirts. If you would like to enter the raffle for one of them, please provide your contact information here: [survey link]

This link will redirect you to another survey to protect your privacy on this survey.

Please copy this link and then select the "done" button to submit your responses.

APPENDIX B - End of Course Survey Questions for Professional Preparatory Course

As a result of this course:
How important do you think licensure is to the practice of civil engineering?

- Very important
- Somewhat important
- Neutral
- Somewhat unimportant
- Not important

How did taking this course impact your opinion on the importance of licensure to civil engineering practice:

- I now think licensure is more important
- I now think licensure is less important
- This course did no impact my opinion on the importance of licensure

How important do you think ethics is to the practice of civil engineering?

- Very important
- Somewhat important
- Neutral
- Somewhat unimportant
- Not important

How did taking this course impact your opinion on the importance of ethics for civil engineering practice:

- I now think ethics is more important
- I now think ethics is less important
- This course did no impact my opinion on the importance of ethics

How important do you think effective writing and verbal communication is to the practice of civil engineering?

- Very important
- Somewhat important
- Neutral
- Somewhat unimportant
- Not important

How did taking this course impact your opinion on the importance of effective writing and verbal communication to civil engineering practice:

- I now think effective writing and verbal communication is more important
- I now think effective writing and verbal communication is less important
- This course did no impact my opinion on the importance of effective writing and verbal communication

How important do you think engagement with stakeholders is to the practice of civil engineering?

- Very important
- Somewhat important
- Neutral
- Somewhat unimportant
- Not important

How did taking this course impact your opinion on the importance of engagement with stakeholders to civil engineering practice:

- I now think engagement with stakeholders is more important
- I now think engagement with stakeholders is less important
- This course did no impact my opinion on the importance of engagement with stakeholders

APPENDIX C - Graduating Senior Survey Questions

In how many semesters were you enrolled in the CE program at CCNY? _____
In how many semesters did you participate in student organizations? ______
In how many semesters did you participate in student organizations in a leadership position? ______
In how many semesters did you participate in research with a faculty on campus? ______
How many part-time fall or spring semester internships have you done while at CCNY? ______
How many part-time or full-time summer internships have you done while at CCNY? ______
How many free engineering/professionalism seminars have you attended on campus? ______
How far along in the program were you when you first signed up for CPDI (Career and Professional Development Institute)?

- First year
- Second year
- Third year
- Fourth year
- Fifth year
- I haven't done this and I don't intend to

Did you take either of these courses?

- CE 100
- CE 101
- Neither

How did these courses impact your passion for the profession of civil engineering?
How did these courses impact your drive to succeed in the CE program?
How did these courses impact your morale when faced with a difficult challenge in the CE program?

- Increased it a lot
- Increased it a little
- Did not impact it at all
- Decreased it a little
- Decreased it a lot

APPENDIX D - End of Course Survey Questions for Technical Preparatory Course

Can you:

- Yes
- A lot
- A reasonable amount
- A little
- No

How much do you attribute this ability to this course:

- Entirely
- Somewhat
- A little
- Not at all, I knew how to do this before I took this course
- Not at all, I didn't learn this in this course

1. Develop study skills that improve student learning and make studying more time efficient
2. Develop group work skills that allow groups to be more efficient and productive
3. Be aware of their responsibilities as a student and prioritize their time to meet these responsibilities
4. Apply theoretical concepts learned in prerequisite math and science courses to civil engineering problems
5. Explain what critical thinking is and use it to solve problems that are unfamiliar
6. Demonstrate critical thinking in how problem solutions are written out to show clear understanding.

APPENDIX E – Fischer's Exact Test p Values for Pairwise Comparisons

Table E-1. Attitudes/Behaviors of Current Juniors and Seniors vs. Current Sophomores

	vs. Sophomores	
	Juniors	***Seniors***
Prerequisites		
Math	1	1
Physics	1	1
Chemistry	0.74	0.25
Computing	0.07*	0.34
English	0.46	0.29
Individual Study Habits		
Read my notes	0.6	0.88
Re-visit and re-solve class or homework	0.65	0.24
Read textbook	0.92	0.48
Find new problems and set them up (but not solve)	0.41	0.46
Find and solve new problems fully	0.28	0.57
Help-Seeking Study Habits		
Attend my instructor's office hours	0.21	0.01**
Attend my TA's office hours	0.04**	0.003***
Attend tutoring	0.87	0.83
Work in a study group	0.21	0.27
Understanding the Curriculum		
How pre- and corequisites work	0.27	0.03**
When courses are offered	0.56	0.67
How to choose my specialization	0.61	0.02**
How to choose my electives	0.42	0.02**
Participating in Extracurricular Activities		
Doing an internship	1.00	1.00
Taking and passing the FE exam	1.00	1.00
Attending free seminars on campus	0.97	0.48
Participating in student organizations	0.67	0.80
Registering with career counseling office	0.70	0.29
Getting involved in research	0.95	0.94
*Significance: *** = 99%, ** = 95%, * = 90%*		

Table E-2. Attitudes//Behaviors of Sophomore, Juniors, and Seniors vs. Attitudes/Behaviors of the Same Cohorts Prior to Beginning Civil Engineering Coursework

	Before Engineering vs. Now		
	Sophomores	***Juniors***	***Seniors***
Prerequisites			
Math	1	1	1
Physics	1	1	0.5
Chemistry	0.3	0.92	0.5
Computing	0.18	0.004***	0.5
English	0.24	0.092*	0.31
Individual Study Habits			
Read my notes	0.31	0.5	0.13
Re-visit and re-solve class or homework	0.69	0.05**	0.06*
Read textbook	0.04**	0.10	0.01**
Find new problems and set them up (but not solve)	0.26	0.01**	0.11
Find and solve new problems fully	0.5	0.03**	0.4
Help-Seeking Study Habits			
Attend my instructor's office hours	0.06*	0.01**	0.001***
Attend my TA's office hours	0.5	0.01**	0.040**
Attend tutoring	0.18	0.5	0.81
Work in a study group	0.04**	0.06*	0.22
*Significance: *** = 99%, ** = 95%, * = 90%*			