Examining First-Year Student Success and Attitudes During Challenging Times

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Abstract

In recent years, educational institutions have experienced unprecedented challenges arising from the COVID-19 pandemic, including changes in course delivery and the pandemic's impact on the preparedness and mental health of incoming students. The consequences of the pandemic were further exacerbated for at-risk populations, including first-generation college students, underrepresented minority (URM) students, and women as the gender minority.

Our team has previously reported on the impact of pre-matriculation credits, supplemental instruction (SI), and the transition to college on academic success in a first-year chemistry course for engineering students, with a focus on gendered differences. In this present study, we have expanded our scope to understand more broadly how, for students starting their engineering studies in 2021, their core identity (gender and race/ethnicity), background (first-generation status and pre-matriculation credits), preconceptions and attitudes, and use of SI correlate with their first-semester grades and their outlook towards their overall studies. To address this goal, we administered surveys at the start and end of the Fall 2021 semester to first-year engineering students at Northeastern University and received a response rate of 65% (485 students, consisting of 191 female-identifying, 292 male-identifying, and 2 non-binary students). Survey responses were paired with corresponding institutional data for grades and SI use.

We found that women had higher grade-thresholds for seeking SI and reported more factors negatively impacting their learning at the start and end of the semester, as well as more pessimistic outlooks towards their general studies compared to men. These differences were observed despite the fact that both genders entered their first-year with a similar number of pre-matriculation credits and received comparable grades. We also found that the overall number of pre-matriculation credits did not impact the number of learning concerns students reported. First-generation and URM students enrolled with fewer pre-matriculation credits, reported a greater number of learning concerns, and received lower first-semester grades than their peers. For female first-generation college students and female URM students, the intersectionality of underrepresented identities resulted in greater adverse outcomes, including more negative outlooks and lower grades, which may have long-term consequences for their retention.

Introduction

The Northeastern University Connections Program was established in 2000 with funding from the National Science Foundation (NSF) to provide SI for female first-year engineering students in an effort to increase retention for women in engineering. We have previously reported on the impact of SI in improving retention for women in engineering taking General Chemistry for Engineers, a fast-paced required course for all first-year engineering majors at Northeastern University [1,2]. Our findings have included a positive correlation between students' final grades in this foundational STEM course and their fourth-semester GPA [3]. Understanding the factors that affect academic outcomes in a gateway general chemistry course holds greater significance with the publication of a recent study that reports that students from underrepresented

populations underperform in general chemistry relative to their well-represented peers when adjusted for academic preparation [4].

The evolving understanding regarding the impact of the COVID-19 pandemic on K-12 students [5] and college students [6] has motivated us to investigate current attitudes and academic outcomes for first-year engineering students more holistically and take a broader scope for our analysis. In this paper, we build upon our previous studies and examine the beliefs and behaviors of engineering students entering in Fall 2021, including longitudinal research analyzing the effects of various pre-college experiences and student attitudes on self-efficacy, SI usage, and first-semester outcomes [7].

Consequences of Preparedness for First-Year Engineering Studies

Pre-matriculation credits, defined as classes taken in high school that are equivalent to college-level courses, have historically been a key indicator of student success in undergraduate STEM education programs [8]. Students receive these credits based on results from Advanced Placement (AP) and/or International Baccalaureate (IB) tests, or through dual enrollment programs at community colleges and other higher-education institutions. We previously have found that engineering students who accumulate a greater number of pre-matriculation credits generally achieve a higher GPA and are more likely to persist in a rigorous engineering environment. Conversely, students with fewer incoming credits tend to have lower retention and graduation rates [7].

Disparities arising from race/ethnicity, family background, and socioeconomic status can affect the ability to obtain pre-matriculation credits and subsequently impact student success. Students from underrepresented populations often face additional challenges in their pursuit of an undergraduate engineering degree. In the United States, URM students are defined by the NSF as women, persons with disabilities, and some minority groups (Black/African American, Hispanic/Latino, and American Indian/Alaska Native). These groups are historically underrepresented in STEM fields compared to their population in the US [9]. For example, the ASEE recently reported that only 24.1% of bachelor's degrees in engineering were awarded to women, 4.7% to Black/African American students, and 13.6% to Hispanic students [9]. The pre-college academic background of URM students, including the number of pre-matriculation credits they accumulated, the quality and rigor of their high school courses, and the availability of pre-enrollment STEM interventions (*e.g.*, summer bridge programs), have been found to significantly impact persistence in undergraduate STEM programs [10]. The lack of representation for Black students in engineering is likely due to the paucity of quality and advanced learning experiences in K-12 school systems among communities with high populations of African Americans [11].

First-generation college students, defined as students for whom neither parent has received a four-year college degree, also encounter a unique set of challenges in the first year of their undergraduate studies, including self-reporting higher levels of stress and depression [12]. First-generation students also typically enter college with less academic preparation for college-level courses and have greater difficulty in demystifying higher education bureaucracy [13]. Ultimately, an intersectional lens may facilitate our understanding of student experiences and

outcomes resulting from gender, race/ethnicity, and other social attributes (*e.g.*, first-generation college student status) within this study [14].

Self-Efficacy, Seeking SI, and the Importance of External Support Systems Among First-Year Engineering Students

SI usage in the first year of an undergraduate engineering program can be an important indicator in predicting student academic achievement [2,7]. Self-efficacy is an attribute that could affect a student's willingness to utilize SI and is defined by Bandura as an individual's belief that they can successfully complete an endeavor [15]. Whitcomb *et al.* reported that male engineering students had more self-confidence than their female peers, although women reported higher self-efficacy in chemistry and grades were comparable between genders [16]. Self-confidence can also be reflected in student expectations for a course, as well as the grade threshold at which they seek help (with a high grade-threshold corresponding to a greater willingness to seek SI). Kessels and Steinmayr reported that female students generally have better attitudes towards, and less avoidance of, help than male students, despite both genders exhibiting equal acknowledgement of the benefits from receiving help [17]. However, regardless of the ability or decision to seek help, the impact of SI has gendered differences as well. Academic performance has been found to be positively correlated with SI attendance in female students but negatively correlated with SI attendance in male students [18]. Among pre-pandemic students, we previously found that female engineering students have a higher grade-threshold for seeking SI [1], are more likely to use SI and with a greater frequency [7], are more likely to find SI helpful [3], and receive greater benefits from SI, in terms of improved grade outcomes [2,7] compared to their male peers.

Whether an individual is a first-generation college student and/or a member of an underrepresented population may also impact their self-efficacy and inclinations to seek help during their first year of college. For example, Whitley *et al.* reported that first-generation students are less likely to seek out institutional resources, such as SI [19]. Engle and Tinto hypothesized that this difference may be due to inexperience with the bureaucratic and social structures of higher education, as well as the lack of familial support resulting from limited interactions with such institutions [13]. Furthermore, the prevalence of low socioeconomic and/or first-generation college student status may impact academic expectations, with URM students often demonstrating greater resiliency (and subsequently, more stable self-efficacy) due to a stronger commitment from their families and communities [4]. The intersectionality of gender and race/ethnicity also appears to play a role: Tolbert Smith recently reported that family and community support has a profound impact on the success of Black male engineering students [20].

Impacts of the COVID-19 Pandemic on First-Year Engineering Students

The COVID-19 pandemic has resulted in profound societal disruptions, including within education. The emergency switch to remote learning in spring 2020 resulted in an unprecedented number of students engaging with online platforms as their primary learning environment. Subsequently, online interactions constituted a larger component of K-12 and higher education than pre-pandemic levels. The success of such learning platforms depends on a variety of socioeconomic and psychological factors external to the virtual classroom, including an

individual's self-efficacy for self-regulated learning (SESRL). Alghamdi *et al.* reported that students that demonstrated higher SESRL were generally more successful (*e.g.*, obtained a higher GPA), regardless of course modality or student gender. However, in virtual settings requiring a higher degree of SESRL, male students exhibited a lower ability to regulate behavior and distraction when compared to their female counterparts [21]. The abrupt transition to either fully remote or hybrid learning has also been accompanied by an observed learning deficit in expected knowledge and skills. For example, a recent review of 42 studies on K-12 learning losses during the pandemic found that students lost about one third of a normal school year, with the pandemic causing larger deficits for lower-income households, as well as greater setbacks in math than reading [5]. A critical ramification of changes in course delivery and learning losses has been an overwhelming decline in mental health among college students: a study of almost 60,000 students from January to June 2021 found that individuals who attended class fully online reported greater distress compared to peers in hybrid classes [6].

The transition to college can be challenging regardless, with the pandemic only exacerbating existing obstacles [22]. One study of over six hundred pandemic-era students found that 95% of surveyed students agreed that high stress is expected in engineering, and 96% indicated that their physical health was negatively impacted by stress [23]. Underrepresented groups are pre-disposed to higher levels of stress due in part to their underrepresentation, with one study reporting that female engineering students exhibited higher stress and anxiety levels compared to their male counterparts, and that first-generation engineering students had higher levels of depression than peers that were not first-generation [12]. For URM and first-generation students in particular, finances can be a troubling concern; the Department of Education recently reported that COVID relief funding allowed almost two-thirds of students to remain enrolled in college throughout the pandemic [24].

Research Questions and Theoretical Framework

This present study focuses on the roles of gender, first-generation status, accrual of pre-matriculation credits, and race/ethnicity on student beliefs, behaviors, and academic outcomes, including learning concerns, attitudes towards help-seeking, use of SI, grades, and outlooks towards pursuit of an engineering degree, to develop a snapshot representative of first-year engineering students at Northeastern University in Fall 2021.

Specifically, we evaluated the following four questions:

- How does a student's core identity (gender and race/ethnicity) and acquired background (first-generation status and pre-matriculation credits) influence their preconceptions of starting undergraduate studies in engineering, their use of SI, and attitudes towards their first-semester studies?
- How does a student's identity and background affect their first-semester grades and their subsequent outlook on pursuing an undergraduate engineering degree?
- How are preconceptions, use of SI, attitudes, and academic outcomes correlated?
- What populations of first-year engineering students are at higher risk of adverse academic outcomes and/or personal experiences that might impact subsequent retention and graduation? Does using SI alleviate such negative outcomes and experiences?

Our analysis is guided by the theoretical framework depicted in Figure 1. We hypothesize that student identity may be considered in two contexts: a core identity (attributes that are inherent to the student) and an acquired identity (attributes that the student gains from their own or their family's experiences). There are two ways in which these identities might contribute to behaviors and attitudes during their first semester as an engineering undergraduate: first, by affecting their pre-enrollment academic preparation, and second, by shaping their perspectives and expectations entering college. Importantly, we hypothesize that both first-semester academic outcomes, as well as student attitudes and behaviors, affect academic success in engineering studies, contributing to SI use and ultimately, retention. This framework complements models previously introduced by others conceptualizing pathways by which students pursue undergraduate engineering degrees [25].

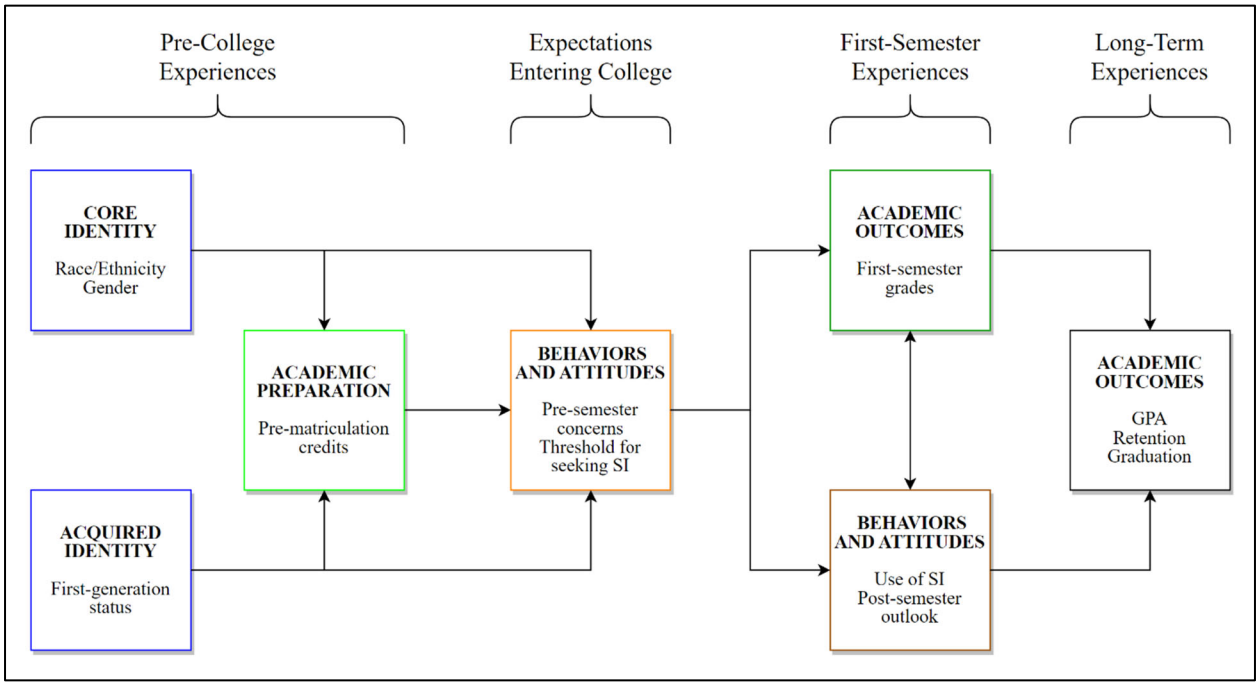

Figure 1: Flowchart of Student Attributes and Experiences

Methods

The students examined in this study were entering first-year undergraduates enrolled in the course General Chemistry for Engineers during the Fall 2021 semester. SI was provided to students in two modalities: group peer tutoring in the form of weekly Connections Chemistry Reviews (led by four female upper-level engineering undergraduates who attended course lectures and offered support remotely using Zoom) and one-on-one peer tutoring available on a drop-in basis through the College of Engineering Tutoring Program (with help offered in-person by a mix of female and male upper-level engineering undergraduates). Further details for this course and its SI have been discussed previously [1-3].

IRB-approved surveys were administered to enrolled students via SurveyMonkey at the start and the end of the semester. Only students aged 18 years or older were eligible to participate in the

surveys, and students could decline to participate. Only students who completed both surveys were included in this study. Survey questions included the student's university-assigned ID number (enabling matching of responses between surveys and with institutional data), gender, whether at least one of their parents had received an undergraduate degree, and a series of questions on their expectations for their chemistry grade and seeking SI, their concerns, and their outlook towards their studies (Table 1). Self-reported grade thresholds for seeking SI were converted from a letter scale to a corresponding 5-point scale (A=4, B=3, C=2, D=1, F=0). Participants could select from a set of nine factors they believed would have (at the start of the semester) or did have (at the end of the semester) a negative impact on their learning; the number of factors selected by a participant in each survey was recorded as their number of start- and end-of-semester concerns, respectively, using a 10-point scale (0 to 9). This is also referred to as "learning concerns." For each participant, an End-of-Semester Outlook Index regarding the student's feelings towards their overall studies was calculated on a 9-point scale (-4 to +4) based on the sum of positive attitudes ("excited", "optimistic", "prepared", "inspired") minus the sum of negative attitudes ("overwhelmed", "discouraged", "bored", "lost"). The following institutional data was available for each participant: final chemistry course average (from instructors), data for race/ethnicity, pre-matriculation credits, GPA (from the Registrar), and attendance for group and one-on-one tutoring (from the College of Engineering).

Table 1: Survey Questions

Survey	Question	Response Options
Start of semester	Indicate the grade you think you'll receive in chemistry	A, B, C, lower than C
	When, based on your grades, would you feel the need to seek out extra help?	Doing very well, but need clarification (A), Doing well but seeking to do better (B), Doing okay (C), Doing poorly (D), Failing the class (F)
	What factors do you believe will have a negative effect on your learning this semester?	The transition to college, Family obligations, Self-confidence, Being away from home and friends, Finances, Physical health, Precautions related to COVID-19, Difficulty focusing, Generalized anxiety/other mental health challenges
End of semester	What factors do you believe had a negative effect on your learning this semester?	
	Please check any of the following that describe your current feelings towards your overall studies.	Excited, Optimistic, Prepared, Inspired, Overwhelmed, Discouraged, Bored, Lost

Our study population consisted of 485 students (191 female-identifying students, 292 male-identifying students, and 2 non-binary students), of which 59 (12.2%) were first-generation college students. Institutional data identified races/ethnicities as either Black/African American, Hispanic/Latinx, White, Asian, International, or other (consisting of students who were two or more races or of an unknown race/ethnicity). Figure 2 depicts the distribution of race/ethnicities for each gender. Given the relatively small number of Black/African American students in our study (7 females and 14 males), our statistical analysis compared differences between URM students (defined as being either Black/African American or Hispanic/Latinx) and non-URM

students (defined as being either White or Asian). The distributions of URM and non-URM students were similar for the two genders: females were 19.4% URM and 70.2% non-URM, and males were 18.5% URM and 64.1% non-URM.

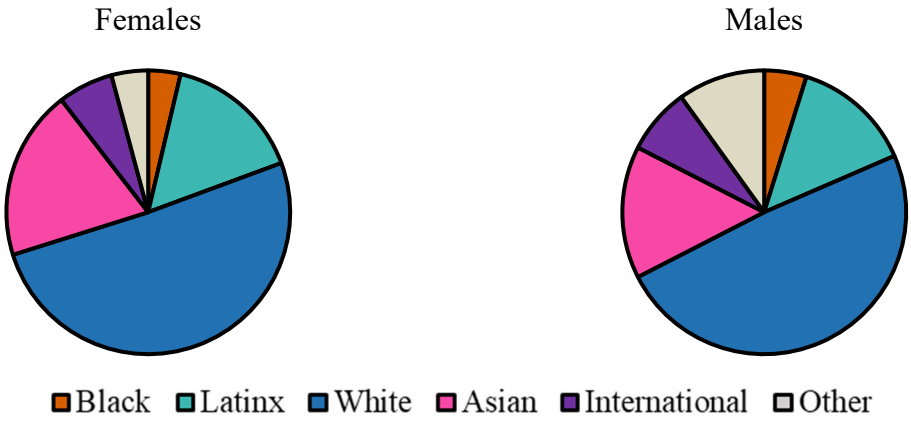

Figure 2: Racial/Ethnic Distributions based on Gender of Students Surveyed

For each student, expected and received chemistry grades were converted from a letter scale to a corresponding 5-point scale, and the difference between the chemistry grade they received and the expected chemistry grade they reported at the start of the semester was calculated on a 9-point scale (-4 to +4) by subtracting the numerical equivalent of their expected grade from the numerical equivalent of their received grade. A more negative value for this difference indicated that the student over-predicted their chemistry grade (*i.e.*, they expected a higher grade than they received), a more positive value indicated that the student under-predicted their grade (*i.e.*, they expected a lower grade than they received), and a difference of 0 corresponded to a student who accurately predicted their grade. SI usage was based on attending at least one SI session, as previously defined.

Survey data and academic outcomes were analyzed using JMP 15 software. Odds ratios were calculated for binary outcomes, with nominal logistic fits used to determine the significance of nominal effects on nominal outcomes. Significance was defined by a probability threshold with a chi-squared test less than 0.05 (indicating a 95% confidence level), and 95% confidence intervals were reported. Two-tailed *t*-tests were used to analyze non-binary results with two subpopulations, with accompanying effect sizes reported as Cohen's d ($d < 0.2$ corresponded to a small effect, $0.2 < d < 0.7$ a moderate effect, and $d > 0.8$ a large effect). One-way ANOVAs were used to analyze results with more than two subpopulations, and the Tukey's HSD test was used to analyze pairwise subpopulations. Two-way ANOVAs were used to compare the effects of two different factors and subpopulations. Results were considered significant if the F ratio was greater than 1 and p less than 0.05. Effect sizes for ANOVA were reported as η_p^2.

Results and Discussion

Role of Gender on Attitudes and Academic Outcomes

To identify a baseline for understanding the attitudes and academic outcomes for first-year engineering students taking a required chemistry course during the Fall 2021 semester, we first examined the role of gender in shaping student backgrounds, expectations, and academic achievements (Table 2). Students who self-identified as female or male had similar distributions of first-generation students and pre-matriculation credits. Furthermore, both genders had similar chemistry course averages, percentages receiving a D, F, or W (withdraw) in chemistry, and first-semester GPA. Males and females equally over-predicted the grade they would receive in chemistry.

Table 2: Influence of Gender on Attitudes and Academic Outcomes

Gender		Female	Male
First-Generation Status		11.5%	12.7%
Pre-Matriculation Credits		14.3±13.1	14.1±13.2
# of Start-of-Semester Concerns		3.31±1.62	2.70±1.67
# of End-of-Semester Concerns		3.59±1.84	2.91±1.54
End-of-Semester Outlook Index		0.06±1.76	0.60±1.91
Grade Threshold for Seeking SI		3.06±0.71	2.89±0.67
SI Usage		30.4%	15.8%
Chemistry Grade	Course Average	86.3±8.3	87.8±7.7
	Received D/F/W	6.3%	3.1%
	Difference Between Received & Expected	-0.30±1.00	-0.23±0.85
First-semester GPA		3.47±0.50	3.50±0.47

Both female and male students reported more concerns negatively affecting their learning at the end than at the start of the semester. However, female students had more start-of-semester concerns ($t(481)=4.05$, $p<0.001$, $d=0.37$), with an associated higher grade-threshold for seeking SI ($t(481)=2.66$, $p=0.008$, $d=0.25$), and more end-of-semester concerns ($t(481)=4.18$, $p<0.001$, $d=0.41$) than their male counterparts. SI usage correlated with experiencing more end-of-semester concerns and an inclination to seek help at a higher course grade: females were 2.33-times as likely to use SI compared to males ($p<0.001$, 95% CI:1.50-3.62). Nevertheless, women ended the semester with a more negative outlook towards their overall engineering studies ($t(481)=4.29$, $p=0.002$, $d=0.29$) compared to men. These observations highlight the dichotomy in personal experiences versus academic outcomes encountered by female engineering students during their first semester: *their academic preparation for college is equivalent, and their academic outcomes are similar to that of their male peers, but female engineering students start their undergraduate studies with a greater number of learning concerns, have higher grade-thresholds for seeking help, and end their first semester with more pessimistic outlooks towards their studies.* Our study supports the findings that Whitcomb *et al.* reported for pre-pandemic students, echoing the disconnect between self-efficacy and grades for women [16].

Role of First-Generation Status on Attitudes and Academic Outcomes

Given previous studies reporting that first-generation college students experience additional challenges [12, 13], we examined the combined effect of first-generation status and gender on the experiences of first-semester engineering students (Table 3). We found that first-generation students entered with a lower number of pre-matriculation credits ($F(1,482)=6.99$, $p=0.008$, $\eta_p^2=0.014$) and had lower chemistry course averages ($F(1,482)=17.55$, $p<0.001$, $\eta_p^2=0.036$) and first-semester GPA ($F(1,482)=8.10$, $p=0.005$, $\eta_p^2=0.017$) compared to their peers who were not first-generation students. Accompanying these poorer grades were adverse personal experiences for first-generation students, including reporting a greater number of learning concerns ($F(1,482)=4.30$, $p=0.039$, $\eta_p^2=0.009$) and a more pessimistic outlook towards their studies at the end of the semester ($F(1,482)=4.06$, $p=0.044$ $\eta_p^2=0.008$).

Table 3: Combined Influence of First-Generation Status and Gender on Attitudes and Academic Outcomes

Gender		Female		Male	
First-Generation Status		First Gen (12%)	Not First Gen (88%)	First Gen (13%)	Not First Gen (87%)
Pre-Matriculation Credits		9.7±12.9	14.8±13.0	9.9±10.2	14.7±13.5
# of Start-of-Semester Concerns		3.91±1.66	3.24±1.60	3.22±2.00	2.62±1.61
# of End-of-Semester Concerns		4.18±2.13	3.51±1.79	3.19±1.78	2.87±1.50
End-of-Semester Outlook Index		-0.82±1.71	0.18±1.74	0.54±2.28	0.61±1.85
Grade Threshold for Seeking SI		2.95±0.90	3.07±0.68	2.84±0.55	2.89±0.68
SI Usage		45.5%	28.4%	18.9%	15.3%
Chemistry Grade	Course Average	79.9±11.5	87.1±7.6	85.6±7.1	88.1±7.7
	Received D/F/W	22.7%	4.1%	2.7%	3.1%
	Difference Between Received & Expected	-0.90±1.29	-0.23±0.94	-0.36±0.87	-0.21±0.85
First-semester GPA		3.18±0.64	3.51±0.47	3.45±0.36	3.50±0.48

First-generation students entered their engineering studies reporting a greater number of start-of-semester concerns ($F(1,482)=7.25$, $p=0.007$, $\eta_p^2=0.015$) as well as more poorly predicting their chemistry course grade ($F(1,482)=9.39$, $p=0.002$, $\eta_p^2=0.020$) compared to their peers who were not first-generation. Note that first-generation status affected neither the grade threshold for seeking SI nor the usage rate of SI. This attitude and outcome may be due to feelings of being overwhelmed and underprepared given their high number of reported concerns and lack of potential familial and community guidance.

We also considered the intersectionality of gender and first-generation status. Based on an ANOVA, interactions between gender and first-generation status were significant only for chemistry course average ($F(1,482)=4.14$, $p=0.042$, $\eta_p^2=0.008$), first-semester GPA ($F(1,482)=4.08$, $p=0.044$, $\eta_p^2=0.008$), and difference between received and expected chemistry grade ($F(1,482)=3.868$, $p=0.050$, $\eta_p^2=0.008$). These observations highlight the significant adverse outcomes experienced by students who were both female and first-generation. A *post-*

hoc analysis with Tukey's HSD revealed that this group of students had lower chemistry course averages and first-semester GPAs compared to other combinations of gender and first-generation status, more strongly over-predicted the chemistry grade they would receive compared to their male and female peers who were not first-generation students, and reported a more pessimistic end-of-semester outlook compared to males (regardless of their first-generation status). Furthermore, female first-generation students were 6.81-times as likely to receive a D, F, or W in chemistry compared to females who were not first-generation students (p=0.003, 95% CI: 1.95-23.80). In contrast, males who had at least one parent with an undergraduate degree had fewer start- and end-of-semester concerns than females (regardless of their first-generation status). We hypothesize that the intersectionality of female and first-generation identities resulted in this population experiencing more negative outcomes compared to females with at least one college-graduate parent, who benefitted from a stronger personal background, or to male first-generation students in the gender majority.

Role of Pre-Matriculation Credits on Attitudes and Academic Outcomes

To further explore the impact of a student's pre-college academic preparation, which we previously found affected the retention of pre-pandemic engineering students [7], we examined the combined effects of pre-matriculation credits and gender on the experiences of first-semester engineering students during the Fall 2021 semester (Table 4). As in our earlier work [7], we divided the population into three groups: students with no pre-matriculation credits, students with up to 20 pre-matriculation credits, and students with more than 20 pre-matriculation credits (approximately equivalent to more than a full semester of college credit). Table 4 shows that, as expected, as the number of pre-matriculation credits increased, both chemistry course average (F(2,477)=31.19, p<0.001, η_p^2=0.115) and first-semester GPA (F(2,477)=27.78, p<0.001, η_p^2=0.104) increased. A *post-hoc* analysis with Tukey's HSD demonstrated that, regardless of gender, students with more than 20 pre-matriculation credits had higher grades than students with no pre-matriculation credits. A student's ability to predict their chemistry grade also depended on their pre-matriculation credits (F(2,477)=7.85, p<0.001, η_p^2=0.032), where (based on Tukey's HSD) male students with more than 20 pre-matriculation credits were better able to meet their grade expectation than students with no pre-matriculation credits of either gender. Additionally, although the number of pre-matriculation credits affected neither the number of start- nor end-of-semester concerns, end-of-semester outlooks became more optimistic as the number of pre-matriculation credits increased (F(2,477)=7.29, p<0.001 η_p^2=0.030), likely as a consequence of the above trends. Lastly, the grade threshold for seeking SI increased as the number of pre-matriculation credits increased (F(2,477)=8.49, p<0.001 η_p^2=0.035). Females with more than 20 pre-matriculation credits had a higher grade-threshold for seeking SI compared either to males (regardless of the number of pre-matriculation credits) or to their female peers with no pre-matriculation credits. Note that the percentages of students who were female were similar among students with no pre-matriculation credits (35.2%), up to 20 pre-matriculation credits (42.1%), and more than 20 pre-matriculation credits (38.8%).

Table 4: Combined Influence of Pre-matriculation Credits and Gender on Attitudes and Academic Outcomes

Gender		Female			Male		
Pre-Matriculation Credits		0 (23%)	1-20 (49%)	21+ (28%)	0 (28%)	1-20 (43%)	21+ (29%)
First-Generation Status		22.7%	9.7%	5.6%	16.0%	13.4%	8.3%
# of Start-of-Semester Concerns		3.20 ±1.56	3.48 ±1.67	3.11 ±1.59	2.68 ±1.75	2.70 ±1.57	2.70 ±1.78
# of End-of-Semester Concerns		3.45 ±1.82	3.57 ±1.88	3.72 ±1.82	3.20 ±1.88	2.83 ±1.33	2.77 ±1.44
End-of-Semester Outlook Index		-0.23 ±1.64	-0.02 ±1.78	0.44 ±1.79	-0.05 ±1.90	0.72 ±1.98	1.06 ±1.64
Grade Threshold for Seeking SI		2.80 ±0.79	3.03 ±0.65	3.32 ±0.64	2.78 ±0.57	2.90 ±0.67	2.96 ±0.74
SI Usage		31.8%	24.7%	38.9%	27.2%	12.6%	9.5%
Chemistry Grade	Course Average	83.8 ±9.3	85.0 ±7.6	90.5 ±7.4	84.1 ±8.3	87.3 ±7.2	91.9 ±5.5
	Received D/F/W	11.4%	5.4%	3.7%	7.4%	2.4%	0.0%
	Difference Between Received & Expected	-0.54 ±1.14	-0.32 ±1.00	-0.08 ±0.83	-0.46 ±0.88	-0.25 ±0.89	0.00 ±0.69
First-semester GPA		3.28 ±0.55	3.45 ±0.50	3.67 ±0.39	3.29 ±0.52	3.46 ±0.46	3.75 ±0.28

Whether a student pursued SI during their first semester depended on both their gender and the number of pre-matriculation credits they had accumulated, with some gender-specific differences. Although the likelihood of females using SI did not vary significantly with number of pre-matriculation credits, males with no pre-matriculation credits were 2.59-times (p=0.009, 95% CI: 1.26-5.30) and 3.54-times (p=0.005, 95% CI: 1.47-8.52) more likely to use peer tutoring compared to males with up to 20 and more than 20 pre-matriculation credits, respectively. Furthermore, females with up to and more than 20 pre-matriculation credits were 2.28-times (p=0.022, 95% CI: 1.13-4.61) and 6.05-times (p<0. 001, 95% CI: 2.43-15.04) more likely to use SI than males within the same pre-matriculation credit categories, respectively. Both genders experienced similar likelihoods of SI usage if they enrolled with no pre-matriculation credits.

Students with no pre-matriculation credits exhibited other noteworthy attributes, behaviors, and outcomes. Students with no pre-matriculation credits were 1.89-times more likely to use SI (p=0.016, 95% CI: 1.12-3.17) and 6.61-times more likely to receive a D, F, or W in chemistry (p=0.015, 95% CI: 1.44-30.43) compared to students with more than 20 pre-matriculation credits. Furthermore, students with no pre-matriculation credits were 2.57-times more likely to receive a D, F, or W in chemistry (p=0.049, 95% CI: 1.00-6.58) compared to their peers with up to 20 pre-matriculation credits. First-generation status is another background attribute correlating with a student's preparedness for academic success. The additional challenges faced by female first-generation students previously noted were compounded by the observation that females with no pre-matriculation credits were 2.75-times (p=0.044, 95% CI: 1.03-7.35) and 5.00-times (p=0.020, 95% CI: 1.28-19.50) more likely to be first-generation students than their female peers

with up to 20 and more than 20 pre-matriculation credits, respectively. In contrast, the likelihood of a male being a first-generation student did not vary significantly with number of pre-matriculation credits.

Role of Race/Ethnicity on Attitudes and Academic Outcomes

Our theoretical framework (Figure 1) postulates that both a student's race/ethnicity and their gender contribute to their core identity, impacting their attitudes at the time of enrollment. To test this framework, we examined how the combination of race/ethnicity and gender influenced the first-semester experiences of engineering students in Fall 2021 (Table 5). Although the first-generation status of Black/Latinx students did not correlate with gender, the relatively small number of Black/Latina female students prevented us from drawing statistically significant conclusions regarding the intersectionality of gender and race/ethnicity on other attitudes or outcomes.

Table 5: Combined Influence of Race/Ethnicity and Gender on Attitudes and Academic Outcomes

Race/Ethnicity		URM (Black/Latinx)		Non-URM (White/Asian)	
Gender		Female (41%)	Male (59%)	Female (42%)	Male (58%)
First-Generation Status		29.7%	29.6%	6.7%	9.1%
Pre-Matriculation Credits		13.0±13.7	7.6±8.3	14.6±13.2	16.7±13.9
# of Start-of-Semester Concerns		3.54±1.73	2.98±2.00	3.31±1.58	2.68±1.65
# of End-of-Semester Concerns		4.14±2.12	3.24±1.93	3.49±1.77	2.83±1.45
End-of-Semester Outlook Index		-0.30±1.87	0.33±1.95	0.06±1.75	0.76±1.95
Grade Threshold for Seeking SI		2.97±0.87	2.78±0.66	3.05±0.66	2.87±0.68
SI Usage		37.8%	25.9%	29.9%	13.4%
Chemistry Grade	Course Average	83.1±10.5	83.8±8.6	87.0±7.5	89.1±7.0
	Received D/F/W	16.2%	5.6%	3.0%	2.1%
	Difference Between Received & Expected	-1.80±1.28	-0.64±0.95	-0.20±0.92	-0.17±0.80
First-semester GPA		3.23±0.64	3.31±0.48	3.52±0.46	3.56±0.45

The intersectionality of core and acquired identities, as well as academic preparation, is a key feature in understanding trends associated with race/ethnicity among students. For example, Black/Latinx students were 4.82-times more likely to be first-generation students compared to their White/Asian peers (p<0.001, 95% CI: 2.64-8.80). Furthermore, in contrast to what we observed for gender overall, first-generation status is slightly more strongly correlated with Black/Latina females than Black/Latino males: Black/Latina females were 5.88-times more likely to be first-generation students compared to White/Asian females (p<0.001, 95% CI: 2.21-15.61), but Black/Latino males were 4.22-times more likely to be first-generation than White/Asian males (p<0.001, 95% CI: 1.95-9.08). Black/Latinx students also enrolled with fewer pre-matriculation credits (F(1,482)=11.75, p<0.001, η_p^2=0.025) than their White/Asian peers. Based on an ANOVA, interactions between gender and URM status were not significant for

first-generation status, but were significant for number of pre-matriculation credits ($F(1,482)=5.54$, $p=0.019$, $\eta_p^2=0.011$).

First-semester academic outcomes—but not end-of-semester outlooks—were correlated with a student's race/ethnicity. In particular, Black/Latinx students had a lower chemistry course average ($F(1,482)=23.09$, $p<0.001$, $\eta_p^2=0.054$) and lower first-semester GPA ($F(1,482)=21.93$, $p<0.001$, $\eta_p^2=0.051$) compared to White/Asian students. Black/Latinx students were also 4.32-times more likely to receive a D, F, or W in chemistry compared to their White/Asian peers ($p=0.004$, 95% CI: 1.62-11.55). This outcome was possibly associated with the increased likelihood that Black/Latina females were first-generation: Black/Latina females were 6.29-times more likely to receive such a grade compared to White/Asian females ($p=0.006$, 95% CI: 1.67-23.65), whereas the likelihoods of Black/Latino versus White/Asian males receiving a D, F, or W in chemistry were statistically indistinguishable.

In retrospect, given the grades they received, Black/Latinx students appeared to underestimate the challenges they might face during the semester, as we similarly noted for first-generation students. This hypothesis is supported by several observations. First, neither the number of start-of-semester concerns nor the grade threshold for seeking SI differed between Black/Latinx students and White/Asian students. Black/Latinx students also more strongly over-predicted the chemistry grade that they would receive compared to their White/Asian peers ($F(1,482)=9.23$, $p=0.002$, $\eta_p^2=0.022$). However, at the end of the semester, Black/Latinx students reported more learning concerns than White/Asian students ($F(1,482)=6.67$, $p=0.010$, $\eta_p^2=0.016$). From a positive perspective, this change was accompanied by seeking help: Black/Latinx students were 1.76-times more likely to use SI than White/Asian students ($p=0.033$, 95% CI: 1.05-2.97). This difference appears to be associated with gendered differences: Black/Latino males were 2.27-times more likely to use SI compared to White/Asian males ($p=0.030$, 95% CI: 1.08-4.75), while an increased likelihood for seeking SI appeared to be a behavior exhibited by females regardless of their race/ethnicity.

Impact of Using SI on Attitudes and Academic Outcomes

As previous studies conducted prior to the COVID-19 pandemic found that using SI in a required general chemistry for engineering course positively impacted first-semester [1] and long-term academic success, particularly for female students [2] and students lacking pre-matriculation credits [7], we were interested in understanding if students entering their first year during the pandemic experienced similar favorable impacts. Table 6 summarizes the combined impact of SI usage and gender on the experiences of first-semester engineering students during the Fall 2021 semester. Note that the grade threshold a student reported at the beginning of the semester did not appear to be a factor that affected whether a student did or did not seek SI.

Table 6: Combined Influence of Use of SI and Gender on Attitudes and Academic Outcomes

Gender		Female		Male	
Used SI		Yes (58)	No (133)	Yes (46)	No (246)
First-Generation Status		17.2%	9.0%	15.2%	12.2%
Pre-Matriculation Credits		13.9±12.7	14.5±13.3	8.5±11.7	15.1±13.3
# of Start-of-Semester Concerns		3.50±1.76	3.23±1.56	3.24±1.73	2.59±1.65
# of End-of-Semester Concerns		6.03±1.30	2.52±0.61	6.00±1.32	2.34±0.61
End-of-Semester Outlook Index		-0.40±1.69	0.26±1.76	0.15±2.07	0.69±1.87
Grade Threshold for Seeking SI		3.14±0.76	3.02±0.68	2.89±0.64	2.89±0.67
Chemistry Grade	Course Average	88.3±8.5	85.5±8.2	86.4±9.3	88.0±7.3
	Received D/F/W	5.2%	6.8%	8.7%	2.0%
	Difference Between Received & Expected	-0.12±1.00	-0.38±0.99	-0.32±0.91	-0.22±0.84
First-semester GPA		3.51±0.49	3.46±0.51	3.49±0.48	3.50±0.46

The findings reported in Table 6 support two independent hypotheses regarding the impact of SI on first-year engineering students during the pandemic:

- SI attracts and generally benefits students who enter with weaker academic preparation and encounter challenges impacting their learning during the semester. Students who participated in at least one session of SI tended to have fewer pre-matriculation credits ($F(1,482)=6.02$, $p=0.014$, $\eta_p^2=0.012$) and more start-of-semester concerns ($F(1,482)=6.10$, $p=0.014$, $\eta_p^2=0.013$) compared to their peers who did not use SI. Students who used SI also reported more end-of-semester concerns ($F(1,482)=1553.90$, $p<0.001$, $\eta_p^2=0.764$) and more pessimistic end-of-semester outlooks ($F(1,482)=8.34$, $p=0.004$, $\eta_p^2=0.017$) than students who did not use SI. Nevertheless, students using SI were able to achieve first-semester grades comparable to their peers who did not avail themselves to SI.
- Women accrue differential benefits from using SI compared to men. Based on an ANOVA, interactions between gender and use of SI were significant for the chemistry course grade ($F(1,482)=5.96$, $p=0.015$, $\eta_p^2=0.012$): females who used SI had higher course averages than females who did not use SI, with the opposite trend observed for males. An associated consequence was that males who used SI were 4.59-times more likely to receive a D, F, or W in chemistry compared to their male peers who did not use SI ($p=0.028$, 95% CI: 1.18-17.79). Similarly, when considering only students who did not use SI, women had lower chemistry course averages than men based on a *post-hoc* analysis with Tukey's HSD, with females who did not use SI being 3.49-times more likely to receive a D, F, or W in chemistry compared to males who did not use SI ($p=0.028$, 95% CI: 1.15-10.66). Note that men who did not use SI entered with significantly more pre-matriculation credits than men who utilized SI; in contrast, there was no correlation between the number of pre-matriculation credits with women who used SI compared to women who did not.

Our observations are consistent with what both we and others have reported for pre-pandemic students [1,2,7,17,18].

Conclusions

For engineering students entering their undergraduate studies in Fall 2021 at Northeastern University, both core and acquired identities, as well as pre-college academic preparation, had a significant effect on their perceptions of college, which in turn impacted their academic performance during the first semester of their first year, as well as their attitudes towards their future studies. We found that:

- Although there were no gendered differences in academic preparation and grades between female and male students, female students had more learning concerns at the start of the semester, had higher grade-thresholds for seeking SI, were more likely to seek SI, and expressed a greater number of learning concerns and more negative outlooks towards their overall studies at the end of their first semester.
- First-generation students entered with weaker academic preparation and experienced more adverse academic outcomes than students who had at least one parent with an undergraduate degree. First-generation students and students entering with no pre-matriculation credits had the most negative outlooks on their studies.
- Black/Latinx students were more likely to be first-generation students, entered with weaker academic preparation, and had worse academic outcomes, although they were more likely to use SI compared to students of other racial/ethnic backgrounds.
- Students using SI entered with weaker academic preparation and expressed a greater number of learning concerns (both at the start and end of the semester), as well as more negative outlooks at the semester's conclusion. Despite these challenges, grades were similar among students who used *vs.* did not use SI, suggesting that users, particular women, benefitted from SI.

These results highlight two critical considerations for supporting pandemic-era first-year engineering students:

- Most students reported more learning concerns at the end of the semester than at the start of the semester, which might be a consequence of the unprecedented educational disruptions at the end of their high school careers due to the COVID-19 pandemic. Females were particularly likely to report large numbers of learning concerns, though the use of SI may have helped to address some of these challenges. However, no correlation was observed between a student's end-of-semester outlook towards their overall studies and their grades. Complicating matters more, most students over-predicted their chemistry grade – a trend that was particularly strong among underrepresented first-generation students and racial/ethnic minorities.
- The intersectionality of identity attributes had a notable effect on beliefs, expectations, and academic outcomes. Females who were either first-generation and/or Black/Latina were particularly at risk of adverse academic outcomes, strongly over-predicting the grade they would receive in chemistry, and ending their first semester with pessimistic outlooks towards their overall engineering studies. In contrast, males with more than 20 pre-matriculation credits appeared to be an advantaged population: they were among the least likely to be first-generation students, they expected and finished the semester with the fewest learning concerns, they were among the best at meeting their grade expectations in chemistry (in part because they had higher grades in general), and they ended the semester with the most optimistic outlooks towards their overall studies.

Two limitations in this current study warrant follow-up. First, the number of students in some at-risk sub-populations, including female first-generation and Black female students, were relatively small, constraining our comparisons. Examining a larger population would overcome this limitation; such a study should incorporate data for socioeconomic status and analyze the potential impacts of participation in summer bridge programs as well. Second, in this study we considered only a simple metric for use of SI: participating in at least one session of group or one-on-one peer tutoring. Assessing the role of frequency or level of engagement in SI, which we have previously shown can be important [3], will be essential in evaluating which forms of SI are most effective going forward.

Our findings suggest the following actions:

- **Identifying—prior to the start of classes—specific students at greater risk of personal and academic challenges** through the use of a short survey administered upon enrollment may allow institutions to direct students to specific support programs that can help to address their individualized challenges and concerns.
- **Strengthening programs and resources for underrepresented students** to provide greater attention to the needs of underrepresented populations—specifically, females, first-generation students, students entering with no previous exposure to college-level coursework, and Black and Latinx students—is warranted, particularly for students who have two or more of these attributes. Tailored strategies might benefit individual groups more than a "one-size-fits-all" approach.

Further research is needed to ascertain long-term outcomes, including retention and degree attainment, for engineering students whose academic experiences (and life overall) were impacted by the pandemic while in secondary school. Students from disadvantaged backgrounds, such as first-generation and URM students, were likely disproportionately affected by the pandemic, further exacerbating pre-existing educational inequalities [13]. Institutions will find that it will not be possible to "return to business as usual," motivating the need to adapt support systems to accommodate for loss of learning and greater mental health burdens [6].

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