A Longitudinal Study of the Effects of Pre-College Preparation and Use of Supplemental Instruction during the First Year on GPA and Retention for Women in Engineering

Mr. Bradley Joseph Priem, Northeastern University

Bradley Priem is a fourth year undergraduate student at Northeastern University, majoring in chemical engineering and minoring in biochemical engineering. He has been involved in the Connections Chemistry Review program for three years. He has also held an undergraduate research position in a biomaterials laboratory on campus. He has completed two co-ops in the biotech industry, and is currently completing his third co-op at a tissue engineering research laboratory at the University of Hannover in Germany.

Ms. Caroline Ghio, Northeastern University

Caroline is a third-year undergraduate student at Northeastern University, majoring in chemical engineering and minoring in data science. She completed her first co-op at a biotech startup working on sustained release drug delivery. Ghio has tutored students as part of the Connections Chemistry program for two years and does research in a biomaterials laboratory on Northeastern University’s campus.

Ms. Hannah Boyce, Northeastern University

Hannah Boyce is a second year undergraduate student pursuing a B.S. in Chemical Engineering and a M.S. in Engineering Management at Northeastern University. She has been involved in the Connections Chemistry Review program for a year, was a Teaching Assistant for Cornerstone of Engineering, holds an e-board position on AIChE, and is involved with ChemE Car. She participates in biomaterials research on campus and has had a co-op at Alivio Therapeutics.

Ms. Sydney Anne Morris, Northeastern University

Sydney Morris is a second year undergraduate student studying chemical engineering at Northeastern University. She has been involved in the Connections Chemistry Review Program for one year, and is also an active member of the university’s chapter of the Society of Women Engineers (SWE) and is on the ChemE Car team. Sydney is also part of the Complex Electrochemical Systems Laboratory on campus where she works with lithium ion coin cells, and she will be completing her first co-op this fall.

Ms. Emma Kaeli, Stanford University

Emma Kaeli is a first-year PhD candidate at Stanford University in Materials Science and Engineering. As a member of the Chueh Group, Kaeli investigates new solid state battery technologies. While an undergraduate, Kaeli earned a B.S. in Chemical Engineering at Northeastern University. In her spare time there, Kaeli enjoyed tutoring and doing survey-based research on the impact of gender on student success in STEM programs.

Mr. Tyler Byrne Cole, Northeastern University

Tyler Cole is a graduate of Northeastern University where he earned a Master’s Degree in Engineering Management and a Bachelor’s Degree in Chemical Engineering in 2018. While at Northeastern, he was involved in the Connections Chemistry Review program and first year engineering tutoring for four years. Tyler currently works as a tech transfer engineer in biopharmaceuticals.

Dr. Paul A. DiMilla, Northeastern University

Paul A. DiMilla is an Affiliate Associate Teaching Professor in Chemistry & Chemical Biology and Chemical Engineering at Northeastern University. During his academic career at Carnegie Mellon University, Boston University, and Olin College he has been the recipient of the first Whitaker Young Investigator Award from the BMES, a Searle Scholar Award, and an Early Career Development Award from the NSF.
as well as a three-time recipient of the Omega Chi Epsilon Outstanding Faculty Award from the Northeastern Student Affiliate of AIChE and the Dick Sioui Teaching Award from Northeastern. He also has led industrial R&D teams at Organogenesis Inc. and Polymerix Corporation developing tissue-engineered medical products and drug-generating biodegradable polymers, respectively, and has co-founded Automated Cell, Inc. In addition to being an inventor on 12 issued US patents, he has published the textbook General Chemistry for Engineers with Cognella Academic Publishing.

Ms. Rachelle Reisberg, Northeastern University

Rachelle Reisberg is Assistant Dean for Engineering Enrollment and Retention as well as Director of Women in Engineering at Northeastern University. Prior to joining Northeastern University, Rachelle held a wide range of management positions in IBM, Hanover Insurance, and was the President of a high tech start-up company.
A Longitudinal Study of the Effects of Pre-College Preparation and Use of Supplemental Instruction during the First Year on GPA and Retention for Women in Engineering

Abstract

The purpose of this study was to evaluate the impact of factors including self-reported gender, first semester GPA, college credit earned in high school, participation in study abroad, major, and use of supplemental instruction (SI) on retention and academic success of 719 undergraduate students who enrolled in engineering during the fall of 2013 at Northeastern University. Our previous research has shown that use of SI in high school resulted in higher course grades and higher GPAs through a student’s fourth semester. This study was undertaken to evaluate the impact of SI and other factors on retention and academic performance over a five-year period.

Data for gender, pre-matriculation college credit, cumulative GPA, major, and registration status at the end of each semester from Fall 2013 through Summer 2018 were obtained from the University for 211 female and 508 male engineering students who entered at the start of the Fall 2013 semester. Data for participation in group and one-on-one tutoring was available from attendance logs for these forms of SI offered to first-year students. This information was analyzed for the effects of gender, number of college credits earned in high school, and participation in first-year SI on retention, graduation rate, GPA, and frequency of both change-in-major and study abroad after each semester.

We found that male and female students’ GPAs at the end of their first semester at Northeastern University correlated positively with not only their fourth semester GPAs, but also their graduation GPAs. Females had higher five-year rates of graduation, as well as higher mean GPAs at graduation compared to males. The amount of college credit earned in high school influenced students’ academic performance in college. A lack of pre-matriculation college credit had a significant negative effect on males, with males without pre-college credit having lower retention and graduation rates and lower GPAs at every time point compared to their male peers who entered with college credit. In contrast, the retention and graduation rates, as well as GPAs of females without pre-enrollment college credit did not differ significantly from their female peers with credits. Overall, females used SI at higher rates than their male counterparts. Furthermore, females entering without college credit used first-year SI at markedly higher rates than their female peers who entered with college credit and male counterparts who entered with and without college credit. In summary, these results show a link between first semester GPA and graduation rates, demonstrate that college-level coursework taken during high school is correlated to college graduation GPA for males, and suggest that SI usage during the first semester of college by females without college credit may explain why females achieve higher levels of academic success throughout their undergraduate careers.
Introduction

Student success and retention in undergraduate engineering programs may be influenced by multiple factors, including prior academic preparation, first-semester experiences, study habits, and gender. Identifying these factors and the extent to which they affect student success is crucial to understanding how to increase retention rates. Supplemental instruction (SI) has been used successfully in academic settings to limit attrition in challenging programs, especially among females. The College of Engineering at Northeastern University has implemented a SI program for first-year engineering students, and our group has identified factors that may predict the use of SI in a required first-semester general chemistry course by these students [1]. For example, students who used SI in high school were more likely to use SI during their first semester in college, showing a correlation between students’ background and how they approach college courses [1].

This paper builds upon longitudinal research assessing the impact of SI usage among students in an engineering program. Our previous research has shown that undergraduates who regularly used SI in first-year general chemistry had higher GPAs in a later semester and at graduation compared to those who did not [2]. We also have reported that females who used SI for first-year general chemistry had a higher GPA after three semesters than males who used SI, but females who did not use SI had a lower third-semester GPA than their male counterparts [1]. Furthermore, it was observed that females found SI to be more helpful in general than their male counterparts [2]. Although this research has provided some insight into post-first year academic success, it has not yet analyzed student success through graduation. Additional research is needed concerning the impact of college-level credits earned while in high school, such as those received through Advanced Placement (AP), International Baccalaureate (IB), and dual enrollment programs, in order to better understand the influence of pre-college experiences on college academic success. This paper reports on the effects of pre-matriculation college credits and the use of SI during the first collegiate year on first- and fourth-semester GPA, retention at these time periods, and five-year graduation rate and GPA for male and female engineering students.

Effects of high school preparation and achievement on retention and success in college

Certain aspects of a student’s academic background have been shown to correlate with their college success. For example, Pike et al. [3] observed that students were 1.19-times more likely to graduate college in four years for every 10-point increase in high school class percentile. High school GPA and ACT/SAT scores alone, however, have not been found to be indicative of college preparedness. Other factors, including high school activities, have been shown to affect subsequent experiences in college [4]. Veenstra et al. [5] found that study habits in high school, such as the amount of time a student dedicated to studying per week, were predictors for a student’s success in their first year of college. Lower high school grades combined with students’ low self-confidence in their academic ability correlated with a decrease in first-semester college GPA [6]. A holistic view of academic achievement and motivation in high school should be considered a more valid predictor of a student’s college performance compared to standardized test scores and GPA alone [4, 5].
College-level credit earned while in high school can also influence academic success in college. Raju and Schumacker [6] found that freshman who entered a large public university between 1995 and 2005 with AP credits had a 21% higher graduation rate than those without AP credits. Similarly, Pike et al. [3] identified that students who took academically intense courses in high school were more likely to graduate college within four years. Moreover, the rigor of a student’s academic experience in high school can impact their academic path in college [3]. Higher SAT scores, overall high school preparation, and more AP credits have been linked with higher enrollment in STEM classes in college [7]. Comparatively, students who did not have access to advanced math or science courses in high school have been shown to be much less likely to pursue an engineering degree, let alone succeed in engineering [8]. Overall, characterizing a student’s high school experience by a combination of standardized test scores, GPA, rigor of course load, and study habits may better predict subsequent enrollment and first-semester grades in a college engineering curriculum than any individual factor.

**First-year college performance and subsequent retention and success**

Similar to how a student’s high school achievement and experiences may be indicative of their first-year success, first-semester GPA also has been found to correlate with retention and GPA at graduation. Students with low grades at the start of their undergraduate studies have been shown to be less likely to be retained within an institution of higher education [4]. For example, a study conducted at the University of Alabama reported a 48% higher graduation rate for students who had a first-semester GPA higher than 3.00 compared to those with a first-semester GPA less than 2.25 [6]. Raju and Schumacker [6] found that first-semester GPA in college along with high school GPA were significant in predicting retention. Students become at-risk for leaving engineering if they do not perform well in their first term because of the fast pace of engineering curricula. Academic difficulty during a student’s early semesters in an engineering program has also been linked with a loss of self-confidence, another factor that negatively impacts retention [5]. As success early on in college is indicative of future college success, perhaps undergraduates who seek academic support early in their studies can increase their likelihood of successfully completing academic coursework and graduating with their desired degree.

**Effect of SI on retention and success**

SI may have positive effects on students that extend beyond the duration of a given course, correlating with the future of a student’s collegiate studies. Many programs use SI because of the beneficial effects it has on retention of underrepresented groups in engineering [9]. Malm et al. [10] have reported that a higher percent of students who used SI passed first-year engineering courses and had higher grades compared to students who did not use SI. Another study found that students who used SI gained 0.02 grade points for each additional SI session attended [11]. SI attendance has been demonstrated to have a positive effect on student performance, regardless of a student’s past academic performance [10]. To benefit from SI, however, students must regularly attend sessions throughout the semester [12].

Although students initially may pursue SI to simply better understand material in a particular course, Grillo and Leist [4] reported that students who took advantage of academic support also had higher GPAs and increased likelihoods of graduating compared to their peers. Furthermore,
students who found SI useful had a greater probability of perceiving their studies as easier to master than they previously expected [2]. Lindsay et al. [13] have noted that students who attended SI were more likely to support each other academically, contributing to an individual student’s social and academic integration. From this perspective, attending SI regularly can be seen as a form of academic integration, and students who are more socially and academically integrated are more likely to be retained [6].

Effects of gender on retention and success

Gender influences patterns of retention and academic success in engineering programs. In engineering majors, men typically outnumber women, as reflected in a 2017 report which revealed only 21.3% of bachelor’s degrees in engineering were earned by women [14]. Despite women earning fewer engineering degrees than men, a positive correlation between being female and graduation rates has been found [3]. Women frequently have been reported to be more likely than men to earn a bachelor’s degree once enrolled, regardless of the time frame needed to earn the degree [15] [16] [17]. The evidence, however, has not been uniform: Lord et al. [18] found no significant difference in four-year retention in engineering between genders for students at nine public universities in the southeastern US, with similar distributions of GPAs at the end of the second year for each gender. French et al. [19] reported that female engineering students had higher cumulative three- and four-year GPAs than males at a large midwestern US institution and that stronger pre-college preparation correlated with higher GPAs for engineering students. Women were also more likely to switch majors and two times more likely to switch out of STEM majors compared to men, although men were more likely to drop out of college [20]. Kamphorst et al. [21] reported that retention within engineering was dictated more by the start of a student’s first year of college for women, compared to experiences throughout their first year for men. SI attendance has also been shown to differ based on gender, with females attending SI at higher rates than males [10].

Research questions

With these background findings in mind, the overall objective for this paper is to analyze the effects of high school and early college experiences, use of SI, and gender on retention, GPA, graduation rate, and other college experiences for engineering students at Northeastern University. In particular, this paper investigates the following questions:

- How indicative is first semester academic performance of subsequent academic success, both during a student’s undergraduate studies and at graduation?
- Does gender affect student academic behaviors (e.g., pre-college education, SI usage, participating in study abroad), as well as retention, within an engineering program during a five-year period? Do differences in academic behaviors affect subsequent retention rates and GPA? Is there a significant difference between male and female graduation GPA?
- What role, if any, do college preparation programs like AP, IB, and dual enrollment have on student success in college? Are there differences in college preparedness depending on exposure to these programs and, if so, how can students with less exposure to college-level courses be supported in order to promote academic success? Does a relationship exist between exposure to college preparation programs in high school and use of first-year SI in college?
Methods

Supplemental instruction

Two types of SI were considered in this paper: student-led group tutoring and one-on-one peer tutoring. Group sessions under the Connections program were organized and led by upper-class engineering students. This program, initially supported by an NSF grant, sought to help freshmen build a strong foundation in chemistry and physics, two fundamental courses in the first-year engineering curriculum which historically students have found very challenging. Student leaders attended lectures, provided review sheets covering the week’s lectures and assignments, assisted with challenging homework problems, and offered end-of-semester reviews in preparation for finals. One-on-one tutoring was available to students for all freshman science, math, and engineering subjects. This walk-in setting was staffed by academically-accomplished engineering students to ensure coverage of all subjects and allowed first-year engineering students to seek individualized help with homework or clarification on lecture topics.

Data collection and analysis

Institutional data as reported each semester by Northeastern University provided metrics on student grades, changes in major, and other academic decisions that affected a student’s course of study. These data were analyzed for the 719 students who enrolled at Northeastern University at the start of the Fall 2013 semester and pursued undergraduate degrees in engineering through programs in the College of Engineering. These students self-identified as 71% male (508 students) and 29% female (211 students). This information allowed for a longitudinal study where key metrics were collected each semester for each student from enrollment through graduation or departure from the program. In addition to the institutional data, attendance logs for group and one-on-one tutoring were used to track student participation in SI.

The combined university-reported data and attendance records for use of SI were analyzed to identify how grades and student academic behaviors influenced student progression or attrition. Results reported in this study focused on the following data:

- Pre-matriculation college credits (e.g., award for scores of 4 or 5 on AP exams, scores of 5 or higher for IB high level exams, or prior college credit received through dual enrollment programs)
- Registration status (including whether a student was studying abroad) during fall and spring semesters
- Cumulative GPA at the start of fall and spring semesters
- Specific engineering major (chemical, civil and environmental, computer, electrical, industrial, and mechanical) registered upon enrollment in the program
- SI usage

Students who entered the university as “undecided engineering” and then subsequently declared for a specific engineering major were not included in determination of rates of changing major.

Data were analyzed for trends as a whole and based on self-identified gender. Z-tests and two-way ANOVA (with Tukey’s HSD post hoc analysis) were used to compare averages among different subpopulations. Proportions among subpopulations were compared based on logistic
regression in terms of odds ratios, reported using 95% confidence intervals (CI). Linear regression was used to correlate GPA after the first semester with GPA after the fourth semester and at graduation. Calculated $p$-values less than or equal to 0.05 were used to identify strong evidence to reject the null hypothesis that differences in proposed subpopulations were due to statistical randomness and thus were considered statistically significantly different.

This longitudinal study incorporated the important element of contemporaneous data for a student’s college experiences including the use of SI and participation in study-abroad programs. A corresponding limitation in this study was that degree completers and non-degree completers were grouped based on gender and number of pre-enrollment college credits with which a student entered the institution. This grouping may have resulted in confounding of significance between effects associated with gender and/or number of pre-enrollment college credits and effects associated with completion/non-completion. For example, students who were not retained for a duration of five years would have had fewer opportunities to participate in a study-abroad program compared to their retained counterparts. Another consideration was that at Northeastern University, computer science is treated as a non-engineering major, which may limit comparison with other institutions for which this treatment is not applicable.

**Results and Discussion**

*Relationship between first-semester performance and subsequent academic success*

The relationship between first-semester GPA and later academic success was first explored. Linear regression was conducted to identify possible relationships between first-semester GPA and fourth-semester GPA (Figure 1) as well as between first-semester GPA and graduation GPA (Figure 2) for the 719 students who enrolled at Northeastern University in 2013 and subsequently pursued undergraduate degrees in engineering. For both comparisons, the datasets were also analyzed by gender. In order to assess the linear correlation of GPAs for each subpopulation, the Pearson correlation coefficient (Pearson’s $r$) was calculated for each condition. These values, provided in Table 1, were used to quantify the strength of these correlations.

![Figure 1: First- and fourth-semester GPAs for female and male students](image-url)
A positive correlation was found between first-semester GPA and fourth-semester GPA in the overall student population (Figure 1). Furthermore, a positive correlation was found between first-semester GPA and graduation GPA in the overall student population (Figure 2). When subdivided by gender, positive correlations between first-semester GPA and fourth-semester GPA, as well as between first-semester GPA and graduation GPA, were still observed (Figures 1 and 2). The positive linear correlations for all of these subpopulations were found to be statistically significant (Table 1). There was no significant difference in correlation strengths between males and females for each comparison (first-semester vs. fourth-semester: \(p=0.303\); first-semester vs. graduation: \(p=0.984\)). Additionally, there was no significant difference in correlation strengths between first-semester GPA and fourth-semester GPA and between first-semester GPA and graduation GPA for either gender (\(p=0.0658\) for females, \(p=0.0734\) for males).

Table 1: GPA Correlation by Subpopulation

<table>
<thead>
<tr>
<th>Correlation</th>
<th>Subpopulation</th>
<th>Pearson’s (r)</th>
<th>(p)-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>First-Semester vs. Fourth-Semester GPA</td>
<td>Overall</td>
<td>0.8087</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>0.7793</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>0.8138</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>First-Semester vs. Graduation GPA</td>
<td>Overall</td>
<td>0.8108</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Females</td>
<td>0.6879</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td></td>
<td>Males</td>
<td>0.6889</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Overall, these findings show that first-semester academic performance may be strongly indicative of future academic success for all students. These findings could be used to stress the significance of first-semester academic success to newly enrolled students. From a student perspective, these findings could encourage students to seek out opportunities for extra help and establish effective study habits early on during their first semester. From an administrative standpoint, assessing a student’s first-semester GPA could be a useful strategy for faculty and advisors to predict which students could experience academic difficulties after the first semester. Such predictions could allow for better targeting of SI to those anticipated to have lower GPAs in
the future, possibly improving the efficacy of such programs. Lastly, these findings corroborate the results of previously-published research that found a similar relationship between first-semester and subsequent academic performance. For example, our previous studies found a positive correlation between students’ final grades in a first-year chemistry course and their subsequent fourth-semester GPA [2]. Together with these current findings, the importance of first-year academic performance can be further stressed as a predictive metric of future academic success.

Gender, retention, and graduation

Student retention is an important metric used to measure the success of engineering programs. In this study, data describing the relationship between gender and retention, including both engineering-specific and university-specific retention, were analyzed. For the 719 students who enrolled at the university in Fall 2013 and subsequently pursued undergraduate degrees in engineering, the percent of students retained after one, two, and five years was calculated for male and female students, both from the perspective of retention within the university (regardless of degree program) and retention within the College of Engineering. These values are reported in Table 2.

<table>
<thead>
<tr>
<th>Population Size</th>
<th>Females</th>
<th>Males</th>
</tr>
</thead>
<tbody>
<tr>
<td>At university</td>
<td>99.53</td>
<td>97.64</td>
</tr>
<tr>
<td>In engineering</td>
<td>94.24</td>
<td>93.32</td>
</tr>
<tr>
<td>At university</td>
<td>97.16</td>
<td>95.28</td>
</tr>
<tr>
<td>In engineering</td>
<td>88.94</td>
<td>87.55</td>
</tr>
<tr>
<td>At university</td>
<td>92.89</td>
<td>87.60</td>
</tr>
<tr>
<td>In engineering</td>
<td>85.31</td>
<td>80.51</td>
</tr>
</tbody>
</table>

Logistic regression was used to analyze the impact of gender on the likelihood of being retained for each retention category at each time point. Although males enrolled in engineering at significantly higher numbers, there was no statistically significant difference in the odds of being retained within engineering between females and males over a five-year period. However, females had a 1.85-times higher likelihood than males of graduating from the university within five years ($p = 0.0402$, 95% CI: 1.03, 3.24). In order to better understand the origin of the disparity in graduation rates between genders, potential differences in cumulative GPA, pre-enrollment college credit earned and use of SI were explored.

Gender and academic behaviors

One of the goals of this paper was to identify the relationship between certain academic behaviors, student gender, and college credits earned while in high school. In order to address this goal, data for pre-enrollment college credits earned, GPA at graduation, change in major,
participation in study abroad, and use of SI were evaluated to learn more about the study population. These statistics can be found in Table 3. Differences between genders were assessed statistically using two-sample z-tests and logistic regression. Note that in this study “changing majors” means changing from majoring in one specific engineering discipline to any other major (i.e., in engineering, STEM generally, or otherwise) within Northeastern University.

Table 3: Effect of Gender on Retention, Graduation, and Academic Behaviors

<table>
<thead>
<tr>
<th></th>
<th>Females</th>
<th>Male</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population Size</td>
<td>211</td>
<td>508</td>
</tr>
<tr>
<td>College credits earned prior to enrollment</td>
<td>20.20±15.13</td>
<td>18.67±15.46</td>
</tr>
<tr>
<td>GPA at graduation</td>
<td>3.53±0.32</td>
<td>3.45±0.36</td>
</tr>
<tr>
<td>% Retained in Engineering after five years</td>
<td>88.12</td>
<td>83.64</td>
</tr>
<tr>
<td>% Used first-year SI two or more times</td>
<td>32.99</td>
<td>18.57</td>
</tr>
<tr>
<td>Number of times used first-year SI</td>
<td>2.45±4.81</td>
<td>1.30±3.63</td>
</tr>
<tr>
<td>% Changed major</td>
<td>43.06</td>
<td>32.39</td>
</tr>
<tr>
<td>% Studied abroad</td>
<td>13.27</td>
<td>3.94</td>
</tr>
</tbody>
</table>

We found that there was no statistically significant difference between pre-matriculation college credits earned by male and female students ($p=0.2199$). At the time of graduation, however, females had a significantly higher average GPA than their male counterparts ($p=0.0033$). Females had a 1.58-times higher likelihood than males of changing majors ($p=0.0247$, 95% CI: 1.06, 2.35) and a 3.73-times higher likelihood than males of studying abroad ($p<0.0001$, 95% CI: 1.52, 3.15). Our findings regarding changing majors are consistent with the report of Hughes et al. [22] that females are more likely than males to enter college intending to major in engineering but then switch and complete a major in a non-engineering field. These results suggest that females may be more open to shifting their academic path and more willing to consider culturally enriching experiences during their path to obtaining a college degree than their male peers. Simmons et al. [23] have reported that females had a greater tendency to favor international experiences compared to males. Salisbury et al. [24] have attributed correlated this gender discrepancy with differences in cultural and social capital developed during the first year in college.

We also observed gender-based differences in both the likelihood of using and the intensity of use of SI during the first year. Females had a 2.19-times higher likelihood than males of using first-year SI two or more times ($p<0.001$, 95% CI: 1.52, 3.15). Females also used first-year SI significantly more times than male students ($p=0.0018$). These differences provide further evidence suggesting that female students are more willing to try new academic behaviors compared to their male counterparts.

Pre-college education and retention

While in high school, some students have the opportunity to enroll in rigorous courses that expose them to learning environments similar to those experienced in college. In particular, academically strong high school students commonly have opportunities to earn college-level
credits through enrollment in Advanced Placement (AP) courses, International Baccalaureate (IB) coursework, and through dual enrollment programs. To explore the impact these pre-college programs have on college readiness and retention for engineering students, the relationship between pre-matriculation college credits and retention was investigated (Table 4). The likelihood of retention at the end of the second year of college was 2.11-times greater for students entering their engineering studies with up to 20 college credits compared to students entering with no college credits ($p=0.0123$, 95% CI: 1.18, 3.79). Further, the odds of students entering with up to 20 college credits being retained in engineering after five years were 2.06-times higher ($p=0.0071$, 95% CI: 1.22, 3.48) than those of students entering with no college credits. However, there was no significant difference in the likelihood of being retained in engineering after five years between students entering with up to 20 college credits and students entering with 20 or more college credits. There was a significant interaction ($p=0.0402$) between gender and entering with either up to 20 college credits or entering with no college credits on the odds of retention in engineering after five years. Females entering with no college credits were retained at a higher rate than their male counterparts, but there was a negligible difference in retention between females and males entering with up to 20 college credits.

**Table 4: Gender and Effect of Pre-college Preparation for Freshmen on Retention**

<table>
<thead>
<tr>
<th>Population Size</th>
<th>0 College Credits Earned Prior to Enrollment</th>
<th>Up to 20 College Credits Earned Prior to Enrollment</th>
<th>20 or More College Credits Earned Prior to Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females</td>
<td>28</td>
<td>85</td>
<td>89</td>
</tr>
<tr>
<td>Males</td>
<td>93</td>
<td>201</td>
<td>195</td>
</tr>
<tr>
<td>% Retained in Engineering after one year</td>
<td>92.31</td>
<td>94.87</td>
<td>93.59</td>
</tr>
<tr>
<td></td>
<td>88.89</td>
<td>94.30</td>
<td>94.12</td>
</tr>
<tr>
<td>% Retained in Engineering after two years</td>
<td>89.29</td>
<td>87.95</td>
<td>88.76</td>
</tr>
<tr>
<td></td>
<td>77.17</td>
<td>90.05</td>
<td>85.57</td>
</tr>
<tr>
<td>% Retained in Engineering after five Years</td>
<td>92.86</td>
<td>96.47</td>
<td>96.63</td>
</tr>
<tr>
<td></td>
<td>78.49</td>
<td>93.53</td>
<td>94.87</td>
</tr>
</tbody>
</table>

These results suggest that participating in college-level academics prior to matriculation in college can increase the likelihood of retention both within engineering as well as within the university overall (the latter based on considering students who transfer out of engineering without leaving the university). These findings support previous literature reporting that students who lack access to advanced high school educational programs are less academically prepared to succeed in college. In particular, our findings for males but not for females are consistent with a recent report from the National Academy of Engineering, which reported that engineering students with a stronger pre-college academic preparation had a higher likelihood of completing their degrees within five years [25]. In our study we found that females had a 3.75-times higher chance of being retained at the university after five years compared to males ($p=0.0313$, 95% CI: 1.08, 5.07), regardless of the number of incoming college credits. This result suggests that,
although there are social and demographic barriers that may inhibit women from entering studies in STEM, women enrolled in engineering at Northeastern University had a greater likelihood of succeeding in an engineering curriculum once enrolled compared to their male peers.

**Pre-college education and academic success**

Pre-college preparedness impacted GPA, with the highest GPA earned by students entering with the greatest number of college credits (Table 5). Using a two-way ANOVA with Tukey’s HSD post hoc analysis, the mean GPAs of each group of students were compared after the first semester, second year, and at graduation. Females had on average higher GPAs than males at each time point and subgroup of pre-enrollment college credits examined. Although college credit earned prior to enrollment impacted both male and female students, the extent to which it did varied between genders.

**Table 5: Gender and Effect of Pre-college Preparation for True Freshmen on SI use and Subsequent Academic Performance**

<table>
<thead>
<tr>
<th>0 College Credits Earned Prior to Enrollment</th>
<th>Up to 20 College Credits Earned Prior to Enrollment</th>
<th>20 or More College Credits Earned Prior to Enrollment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Females</td>
<td>Males</td>
<td>Females</td>
</tr>
<tr>
<td>Population Size</td>
<td>28</td>
<td>93</td>
</tr>
<tr>
<td>GPA after 1st semester</td>
<td>3.41±0.52</td>
<td>3.09±0.72</td>
</tr>
<tr>
<td>GPA after 2nd year</td>
<td>3.31±0.38</td>
<td>3.11±0.47</td>
</tr>
<tr>
<td>GPA at graduation</td>
<td>3.36±0.30</td>
<td>3.25±0.36</td>
</tr>
<tr>
<td>% Used 1st-year SI two or more times</td>
<td>55.56</td>
<td>20.45</td>
</tr>
<tr>
<td>Number of times used 1st-year SI</td>
<td>5.37±8.27</td>
<td>1.56±3.74</td>
</tr>
</tbody>
</table>

We also found that males with no pre-enrollment college credits had a significantly lower average first-semester, fourth-semester, and graduation GPA than every group (regardless of gender) with more pre-enrollment college credits. In particular, first-semester GPA for males with no pre-enrollment college credits was markedly lower than their peers. Furthermore, males with between 0 and 20 pre-enrollment college credits had a significantly lower fourth-semester GPA than males with more than 20 pre-enrollment college credits. Male GPA rose significantly with the addition of college-level coursework in high school. For males, the impact of pre-enrollment college credit continued throughout their matriculation at the university, with a strong positive correlation between number of pre-enrollment college credits and GPA at each data point examined. It is possible that males lacking pre-matriculation college credit also entering their engineering studies with other academic disadvantages, such as coming from challenging socio-economic backgrounds and/or with inadequate role models, although data for such attributes were unavailable for the population in this current study.
Pre-matriculation college credit had a lesser impact on the academic success of female engineering students. GPA for females correlated positively with number of pre-enrollment college credits, although not as noticeably as it did for men. The impact was most significant for female students who had 20 or more pre-enrollment college credits: GPA for this group was significantly higher after the first and fourth semesters and at graduation compared to the GPA of female students who enrolled with less than 20 college credits. We note that the difference in GPA between groups with no and at least some pre-matriculation college credits was larger for males than for females.

**SI use, pre-college education, and gender**

The use of SI was also linked to gender and pre-enrollment college credits earned: pre-enrollment college credits, or the lack thereof, influenced use of SI and was an accurate predictor of use of SI particularly among female students. Table 5 shows that female students with no pre-matriculation college credits used SI significantly more than other groups. Female students with between 0 and 20 pre-enrollment college credits had a 2.10-times higher odds than students entering with 20 or more college credits of using first-year SI two or more times ($p=0.0004$, 95% CI: 1.39, 3.16). These results also corroborate our previous findings that students who were more confident that they would receive a high grade in a first-year general chemistry course at the beginning of the course had a higher average grade threshold for seeking SI [26] and that females had a higher trigger point for seeking SI than males [27]. Our current findings suggest that students with less pre-matriculation exposure to rigorous college engineering curricula are less academically prepared to excel in college compared to those with greater exposure to college-level studies. Students with less pre-enrollment college credit consequently are more likely taking advantage of SI offerings during their first year, whereas students with more pre-college preparedness may not feel the need to do so.

The disparity in SI usage was reflected in a disparity in GPA between male and female students, particularly among those with no college level credit earned in high school. The use of SI by females with no pre-enrollment college credits at the rate of 55.56% may have contributed to their ability to maintain a GPA of 3.41 ± 0.52 their first semester. This correlation for females is consistent with our previous report that the less exposure female students had to chemistry prior to college, the more likely they were to benefit from extra help resources for general chemistry [27]. In contrast, only 20.45% of men with no pre-enrollment college credit used SI, and males entering without college credit had a first semester GPA of 3.09 ± 0.72.

**Conclusions**

The strong positive correlations between first-semester GPA and fourth-semester GPA, as well as between first-semester GPA and graduation GPA demonstrated that early academic success was predictive of subsequent academic achievement during a student’s tenure. This finding highlights the importance of first-year success and could be a useful metric for both students and administrators to predict future academic behavior and to adjust study habits and extra help use accordingly during the first year.
After five years of study, female engineering students had higher retention rates at the university as well as higher graduation GPAs compared to their male counterparts, despite females enrolling at lower numbers in engineering. Analysis of various behaviors revealed that female engineering students used SI, changed their majors, and studied abroad at a higher frequency compared to their male counterparts. The increased activity of these academic behaviors could imply that female students are more likely to traverse their college experience open to shifting their academic path and more likely take advantage of academic offerings than their male counterparts. It is possible that this increased likelihood of participating in such behaviors could play a role in female students’ higher five-year retention rate and graduation GPAs.

Analysis of data describing pre-matriculation coursework and credit was of particular interest. Entering an engineering curriculum without having earned previous college credit had a greater negative effect on male engineering students than on their female counterparts. Male engineering students entering without previous college credit experienced lower rates of retention and graduation as well as lower GPAs than their male peers entering with previous college credit. Interestingly, the rates of retention and graduation, as well as GPAs, of female students did not differ significantly based on amount of college credit earned prior to enrollment. One possible interpretation for these differences in gender-specific outcomes is that differences in their willingness to engage in academic experiences also may have led to differences in their willingness to use SI and partially overcome the negative impact that lack of college-level academic coursework in high school might otherwise impart on graduation rates and GPA. This perspective concurs with comments in a recent report from the National Academy of Engineering that college experiences can result in changes in engineering students' social and academic self-concepts that induce gains in academic self-concept [24].

The relationship between college credit earned in high school and first-year SI use also was assessed. It was found that females entering with no pre-enrollment college credit used first-year SI more frequently than their female peers entering with pre-enrollment college credit. In contrast, male students had similar frequencies of use of first-year SI, regardless of their amount of pre-enrollment college credits. An interpretation of this finding could be that female students with no pre-enrollment college credit are more likely to reach out for extra help during their first-year than their male peers who also have no pre-enrollment college credit. It has been found both in this paper and in previously published research that female students are more likely to use SI than males [2]. Focusing on students entering college with no prior earned college credit, it is possible that this increased likelihood for females to use SI compared to males could explain how the use of SI helped first-year female students lacking advanced coursework in high school to achieve higher five-year retention and graduation GPAs than their male counterparts. Female students lacking prior college credits could have used first-year SI to compensate for their lack of college experience, while their male counterparts did not take advantage of such offerings to the same degree.

In summary, these findings indicate:

- The transition to college during the first semester was critical for engineering students at Northeastern University: GPA at end of first semester was predictive of cumulative GPA at end of sophomore year and at graduation for both genders.
Female engineering students had higher retention rates over a five-year period and graduation GPAs than their male counterparts.

Females used first-year SI, changed majors, and studied abroad more frequently than males.

Entering an engineering curriculum without having previously earned college credit while in high school had more serious negative effects on males than on females: males without pre-enrollment college credit had lower retention and graduation rates and lower GPAs than their male peers who entered with college credit. However, the retention, graduation rates and GPAs of females did not differ significantly based on the amount of college credit earned prior to enrollment.

Females entering without college credit used first-year SI more frequently than their female peers who entered with college credit. In contrast, the frequency of use of first-year SI by males did not differ significantly based on the amount of college credit earned prior to enrollment.

In future studies, it is suggested that analysis of the reasons females change majors at higher rates than males and of female willingness to engage in new academic behaviors be conducted in relation to academic success. It would also be of interest to explore possible differences and similarities of these findings for underrepresented minorities as well as socio-economic and other personal attributes that might contribute to the decreased retention and GPAs of males lacking pre-matriculation college credit. Further attention towards programs designed to impact retention beyond the first and second years of study in engineering programs also may be warranted.

References


