Role of Gender and Use of Supplemental Instruction in a Required Freshman Chemistry Course by Engineering Students on their Course Grades and Subsequent Academic Success

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Abstract

This study analyzed correlations by gender between student attitudes toward supplemental instruction (SI) for a freshman chemistry course for engineering students and their grades both at the end of the course and throughout their subsequent course of study. General Chemistry for Engineers is a required course for all students in the engineering program at Northeastern University and is taken during a student’s first semester at the university. SI for the course included structured group review sessions, one-on-one peer tutoring, and office hours held by teaching staff.

Previous research has found that there are statistically significant correlations between the use of SI and improved term and overall GPAs while in college.[1] Further, evidence suggests that the way students start their college career often indicates how they will finish. [2] At Northeastern University, General Chemistry for Engineers is the first challenging course a student entering the engineering program takes that serves as model for subsequent coursework in the full engineering curriculum. Among engineering students, where historically males are the majority, females often have been seen as the primary seekers of SI. Retaining female students in engineering and enabling their overall academic success has been a subject of great importance for engineering programs.

The first portion of this study focused on the grade progression of the students enrolled in the freshman chemistry course from Fall 2007-2012. Correlations were examined among GPA at graduation, GPA after four semesters in college, and course grade for a subpopulation representing 15.9% (409 out of 2572) of the students enrolled in the course during the study time period who attended at least one session of a weekly group review led by upper-level female tutors. Positive correlations were observed among student grades in the course and GPA after four semesters and at graduation, regardless of gender. Females, however, were more likely to receive higher grades in freshman chemistry and have higher subsequent GPAs.

Correlations among gender, attitudes towards SI, and academic success then were assessed based on data for surveys administered at the start and end of the freshman chemistry course for 54.3% (497 out of 916) of the students participating in the course during the latter part of the study period in the Fall 2011 and 2012 semesters. This study found that students finding SI useful were more likely to perceive that a rigorous required freshman chemistry course was easier to master than anticipated. Further, the frequent use of SI in the course was predictive of long-term academic success: students regularly attending a structured peer tutoring session as a form of SI were more likely to have a higher GPA at graduation than their peers who were infrequent attendees, regardless of gender. Finally, females, when offered either a social or one-on-one form of SI, were more likely to find at least one of these resources helpful, much more likely to attend structured reviews led by females who could act as role models, and rate one-on-one tutoring more helpful than their male peers.
Background

The study discussed in this paper was conducted in order to determine statistically significant trends within a population of engineering students who participated as first-semester freshmen in a required general chemistry course for engineers. Correlations were drawn among students’ grade in the course, use of and attitudes toward supplemental instruction (SI), and their grade point average (GPA) at the end of their first and fourth semesters as well as at graduation.

A student’s performance in his/her first semester in college often has been linked to the student’s later level of achievement during his/her college career and retention of that student in an engineering program. [3] As retention is a priority of many universities, it is critical to understand the correlations between student success and other measureable factors in order to anticipate potential difficulties for students and offer support for students who need it. Programs designed to successfully provide this support could have a foreseeable impact on a student’s college experience, including the teaching of skills like time management, establishment of studying tactics, and development of problem solving abilities necessary for later success.

Two major concerns for many engineering programs are the first year retention of students and their subsequent overall graduation rates, with particular concerns for female engineering students. It has been reported that the probability of graduation for engineering students increases as overall GPA of the student increases, and males are more likely to graduate than females. [4] In contradiction to this finding, another study examining data from nine universities across the United States concluded that women have higher graduation rates both from the engineering programs and from the universities overall. [5] The GPA of males were higher than females at graduation, though this gap appeared to close once age and experience, including participating in college-level courses during high school and the completion of AP courses, were factored into the statistics. [4] GPA was a greater predictor of retention and eventual graduation for male students than female students. Meanwhile, moderate to high levels of achievement increased levels of confidence in females but accentuated female students’ social discomfort as a minority, making self-doubt and social discomfort better predictors of graduation rate for females than GPA. This trend was valid when women were both a numerical minority in classes and were stereotyped, as women often are in engineering programs. [4]

The existing literature suggests that factors other than just GPA impact a female student’s decision to remain in and eventually graduate from an engineering program. For example, self-efficacy, or a specified level of achievement and the strength of a student’s belief that the level of achievement can be attained, has been shown to be a good indicator as to whether or not a student will remain in and graduate from a STEM program. Female students who graduate in engineering programs have higher self-efficacy than females who drop out of engineering programs, and male engineering students consistently have higher self-efficacy than female engineering students. [6]

How engineering students start their college careers can impact how they will finish, as the level of academic achievement demonstrated during their first semester in college often is sustained long-term. [2] This observation suggests that focusing on how an engineering student of either gender performs in his/her first challenging college class during their freshman year is important
as it may be a predictor for overall college success. There are a variety of features that such a course should engage, including developing the ability to identify, formulate, and solve contemporary global and societal problems, creativity, communication skills, high ethical standards, and the importance of lifelong learning. The incorporation of using technology and outside resources in developing these skills also are important elements. [3] General Chemistry for Engineers, a course taken by first-semester freshmen at Northeastern University, encompasses all of these requirements in addressing the needs of entering engineering students while satisfying ABET criteria. [7] Chemistry also is a course that balances conceptual and quantitative elements in a framework that favors neither females nor males.

Supplemental instruction (SI) is a widely-used instructional technique at many universities implemented to help students succeed in a college course and better understand material covered in class. SI can consist of office hours offered by an instructor or teaching assistant (TA), group or one-on-one peer tutoring, group review sessions, promotion of student-led study groups, or a combination of these offerings. Many studies show that students who utilize SI earn higher term and overall GPA as well as more timely graduation rates than students who do not utilize SI offerings. [8] [9] [10] Studies also show that there is a statistically significant correlation between higher term GPAs and more time spent in SI. [1] [11] [12]

It has also been found that factors that are not easy to measure, such as long-term retention of course information, communication skills, teamwork, and information processing skills, are improved when students engage in SI. [8] Students who take advantage of SI have been found to have a better attention span, could study for longer periods of time, were less dependent on “last minute” studying, and were more accustomed to being helped or helping other classmates understand difficult course work. [13] These findings support a similar study that determined students who not only found extra resources (e.g. recitation, on-line availability of materials, course textbook, and class handouts) provided by the instructor useful but also took advantage of these resources received a higher final grade in general chemistry. [14] It is reasonable to anticipate that these higher grades in a first-semester freshman chemistry course correlate to higher GPA at graduation for engineering students, for the skills learned freshman year can be useful throughout the entire engineering curriculum.

While previous studies have shown that male and female students benefit equally from SI, there are significant differences between the genders in attitude towards the use of SI. [15] Female students tend to use SI more often, are more comfortable asking for help, and have a more positive view of SI than male students. [16] These trends can be attributed to a variety of factors. Female students tend to ask more questions and to be viewed as “dependent” when asking for help, while male students feel a greater threat to their self-confidence and perceived abilities if they require help to succeed in their coursework. [17] Data from previous studies of the effect of SI on success of females and males in a first-semester freshman chemistry course support these claims. [18] [14] [19] Many studies also suggest that female students not only have a more positive attitude towards their studies but also are more intrinsically interested in learning and coursework. [20]
Methods

Study Model

The data for this study consisted of students enrolled in a course entitled “General Chemistry for Engineers” during the Fall 2007 through Fall 2012 semesters. This course, required for engineering students at Northeastern University, typically is taken during the fall of a student’s freshman year, with the exception of students with credit for AP Chemistry or IB Chemistry or transfer credit from another institution for an equivalent course. The class was divided into general sections as well as honors sections, the latter open only to students who were admitted to and enrolled in the University Honors Program. This study focused on students enrolled in the general sections. Students attended this course weekly in the form of three 65-minute lectures, led by an instructor to sections of approximately 100 students, and one 100-minute recitation, led by a graduate-student teaching assistant (TA) to sections of approximately 30 students. Course grades were based on homework assignments, weekly quizzes, recitation attendance, midterm exams, and a final exam. [14]

A variety of resources for SI were offered, with the primary focus on students in the general sections. All respective SI sources were made known to enrolled students on the first day of class and emphasized by instructors and academic advisors throughout the semester. Students were offered weekly Connections Chemistry Reviews, group review sessions run by three upper-class tutors majoring in chemical engineering. These tutors were all female undergraduates for the time period studied, and attendees were both male and female. These weekly evening sessions consisted of a review of key concepts and skills introduced in lecture followed by time to address homework problems and for additional questions. As a supplement to lectures, select instructors held 60-90-minute review sessions before each exam as well. In addition, there were multiple walk-in services for SI available throughout the time period of this study. Instructors and TA’s held weekly office hours outside of class during which attending students could ask specific questions and receive help one-on-one and in small groups. Northeastern University’s College of Engineering (COE) offered one-on-one help through the COE Tutoring Office staffed weekdays by a mix of male and female graduate and upper-class undergraduate engineering students. These graduate and upper-class undergraduate tutors were not the same tutors as those for the Connections Chemistry Reviews. The Department of Chemistry and Chemical Biology offered “Chem Central” as a resource for students to receive one-on-one and small group help on a walk-in basis weekdays from a faculty member or TA in the department. Students also were encouraged to create study groups with peers taking the course. All SI services were free of charge to students in the course. [14]

Data Collection and Statistical Analysis

Data were gathered from (1) grades and attendance provided by instructors for students in the general sections of General Chemistry for Engineers for the Fall 2007-Fall 2012 semesters; (2) GPA after one semester, four semesters, and at graduation provided by the Office of Student Services for students who attended at least one Connections Chemistry Review during the Fall 2007-Fall 2012 semesters; and (3) IRB approved surveys administered to students enrolled in the general sections of General Chemistry for Engineers during Fall 2011 and Fall 2012 semesters. Pre-surveys were administered during the first meetings of recitation at the beginning of the
semester. The purpose of the pre-surveys was to gather information from students about their expectations, general experiences, and past academic performance and use of SI in chemistry. Post surveys were administered during the final meetings of recitation at the end of the semester. The purpose of the post surveys was to determine attitudes of the students toward outcomes of the course and their use or lack thereof of SI. A student code specific to each student was used to match data from pre- and post-surveys in order to connect expectations and outcomes with data supplied by instructors. This identification method allowed for confidentiality of information gathered from surveys and instructors.

Results reported in this study based on pre- and post-surveys focused on student responses to the following questions posed in surveys:

1. Chemistry is a hard subject to understand.
2. Understanding chemistry is important to being a successful engineer.
3. I worked hard in this class.
4. Rate the usefulness of Monday night Connections Reviews.
5. Rate the usefulness of Chem Central.
6. Rate the usefulness of COE Tutoring Center.
7. Rate the usefulness of instructor office hours.
8. Rate the usefulness of studying in groups.

Questions 1-3 were answered as either “yes” or “no” and posed in both pre- and post-surveys. For Questions 4-8, posed only in post-surveys, a Likert rating scale of 1 to 5 was used where 1 was low and 5 was high. [18][14]

A statistical analysis with the collected data was used to determine which variables (e.g. final grades, gender, use of SI) were statistically correlated. Two types of tests were used to determine if relationships were statistically significant. (1) A t-test was used to determine if there was a statistically significant difference between mean values for a variable for two sample groups of two independent populations (e.g. final grades for males and females). Using sample sizes, standard deviations, and mean values, p-values were calculated for each test. (2) A two proportion Z-test was used to determine if there was a statistically significant difference between the two percentage values (e.g. percent of females and males who used SI). Using a normal distribution, sample size, and percentage values, p-values were calculated for each test. For both statistical tests, if a calculated p-value was equal to 0.05 or below, the null hypothesis that there was no significant difference was rejected, and the alternate hypothesis that there was a difference was accepted. [21]

Results and Discussion

Correlation Between Four-Semester and Graduation GPA

In this study, data were collected for a population of approximately 2,500 students consisting of engineering students who participated in the freshman chemistry course during the fall semester from 2007 to 2012 at Northeastern University. Table 1 outlines the gender distribution of the
groups assessed. Analysis was performed based on data for grades and attendance for students who attended the Connections Chemistry Review (weekly group review sessions run by upper-class tutors), representing 17.8% (457 out of 2572) of the students enrolled in the course during the full study time period, as well as pre- and post- survey data from 54.3% (497 out of 916) of the students participating in the course during the Fall 2011 and 2012 semesters. Of the students whose grade/attendance data were collected, 39.4% were females (180 out of 457) and 60.6% males (277 out of 457). Of the population surveyed, 21.9% were females (109 out of 497) and 78.1% males (388 out of 497).

Table 1: Demographic data of students surveyed

<table>
<thead>
<tr>
<th>Year</th>
<th>Males</th>
<th>Females</th>
<th>Total</th>
<th>Males</th>
<th>Females</th>
<th>Total</th>
</tr>
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<td>21</td>
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<td>23</td>
<td>54</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2009</td>
<td>53</td>
<td>43</td>
<td>96</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2010</td>
<td>42</td>
<td>31</td>
<td>73</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2011</td>
<td>38</td>
<td>38</td>
<td>76</td>
<td>218</td>
<td>58</td>
<td>276</td>
</tr>
<tr>
<td>2012</td>
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<td>24</td>
<td>117</td>
<td>170</td>
<td>51</td>
<td>221</td>
</tr>
<tr>
<td>Total</td>
<td>277</td>
<td>180</td>
<td>457</td>
<td>388</td>
<td>109</td>
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</tbody>
</table>

One of the primary research questions for this study is how factors from a student’s experience in a required chemistry course as a freshman impact his/her subsequent academic performance, including in particular GPA at graduation. However, not all of the students surveyed at Northeastern University are members of classes that have graduated to date. In order to identify common trends among all students assessed, both those graduated and not yet graduated, GPA after four semesters in college was examined as a predictor of GPA at graduation. A regression analysis (Figure 2) was performed to determine if these two GPAs were correlated. An R$^2$ value of 0.908 (n = 239) was found for the overall population including both genders, indicative of a strong correlation between the two GPA. The correlation was very similar irrespective of gender (males: $R^2 = 0.916$, n = 132; females: $R^2 = 0.893$, n = 107). These observations supported using a student’s GPA after four semesters as predictive of performance in their later studies. Further, based on this correlation, subsequent analysis performed focused on the larger population of students for which GPA after four semesters but not necessarily at graduation was available.
This study then assessed whether the grade received by a student in freshman chemistry correlated with GPA after four semesters. A regression analysis (Figure 2) demonstrated that the two metrics for academic performance were correlated, albeit with a weaker correlation ($R^2 = 0.554$, $n = 405$) than observed for the relationship between GPA after four semesters and at graduation. Although General Chemistry for Engineers is the first course for an engineering student at Northeastern University that introduces the format and level of challenge one typically encounters in their subsequent college studies, there will be some students who enter with poorer preparation and/or interest in chemistry but can demonstrate stronger academic performance in their overall curriculum. The correlation between grade in chemistry and overall GPA, however, is robust enough to suggest performance in freshman chemistry is a general predictor for subsequent academic success.
Further analysis then was conducted to identify relationships among gender, grade in General Chemistry for Engineers, and GPA after four semesters. Figure 3 shows histograms of grades in chemistry and four-semester GPA for each gender. Females had both statistically significantly higher grades in freshmen chemistry and overall GPA after four semesters than males based on the mean for each gender and a two-sample one-tailed t-test. These results, together with the results presented earlier in this study, predict that females will have higher GPAs at graduation than males. Subsequent confirmation of this prediction for this population requires more time for students in the population examined to complete their baccalaureate studies in engineering.

Figure 3: Distribution of grades in freshman chemistry (top) and GPA after four semesters (bottom) for males (left) and females (right).

Correlation of Attitudes and Use of Supplemental Instruction with Student Success

Confirmation of female success overall was followed by investigation of success factors that led to their improved performance over males, specifically those related to SI. In order to determine the relevance of SI for student success, the use of resources for SI and student responses to survey questions for the Fall 2011 and 2012 semesters were analyzed. A series of statistical analyses were performed to identify and understand possible correlations.

In surveys students enrolled in General Chemistry for Engineers during the Fall 2011 and 2012 semesters answered questions about how difficult they predicted college-level study of chemistry would be and how challenging it actually was after completing the course. Respondents also indicated how useful they perceived SI was during the course. Figure 4 compares responses for the usefulness of SI for the overall population with the sub-population who reported chemistry was less difficult than anticipated at the start of the semester. Based on a one-sample one-tailed
t-test, those students who felt the study of chemistry was easier than anticipated tended to find SI more useful than the overall population. This result suggests that use of SI tended to aid student understanding and allowed a student to feel they were succeeding in the course.

**Figure 4: Usefulness of SI and its relationship to understanding chemistry**

In order to determine whether the perceived increased value and use of SI corresponded to a type of student that would achieve success throughout his or her university career, the possible relationship between attendance at Connections Chemistry Reviews and GPA after four semesters was analyzed (Figure 5). Using a two-sample one-tailed t-test, it was confirmed that those who attended reviews frequently (5 or more times) had a higher graduating GPA than those who attended infrequently (1 or 2 times). This outcome was true for both males \((p = 3.7 \times 10^{-4})\) and females \((p = 0.05)\).

**Figure 5: Comparison of GPA after four semesters between students who attended the Connections Chemistry Review frequently (5 or more times) and infrequently (1-2 times).**
Students’ perceptions of the connection between an improved grasp on the subject of chemistry and SI suggests that perceiving SI as useful can lead to course success. Furthermore, the confirmation that increased use of one such form, the Connections Chemistry Review, correlated positively with long-term success supports the model that successful students make use of SI. Together, these outcomes predict that the use of SI may be predictive of both short-term success in an individual course based on course grade and long-term success based on overall GPA at graduation, regardless of gender.

**Correlation of Gender, Use of Supplemental Instruction, and Attitudes with Student Success**

Understanding why females pursuing engineering degrees demonstrated stronger academic performance—assessed in terms of higher grades in freshman chemistry and higher GPA after four semesters—compared to their male peers was an important research question for our study. The observation that positive attitudes towards and increased use of SI led to both short-term and long-term success, therefore, prompted examination of whether females tended to make use of and feel more positively toward SI than males. In order to confirm this hypothesis, differences in the self-reported usefulness of SI between genders was assessed (Figure 6). It was determined with 90% confidence using a two proportion Z-test that more females found one or more forms of SI to be useful (based on reporting a score of 4 or 5 out of 5 for a form of SI offered) than did males. Furthermore, females were statistically much more likely than males to be frequent attendees at Connections Chemistry Reviews based on a two proportion Z-test ($p = 3.9 \times 10^{-29}$).

![Figure 6: Percentage of males versus females who found SI useful. Dark color: found at least one form of SI useful; light color: did not find a form of SI useful.](image)

In order to identify what factors contributed to a difference in use of SI for the different genders as well as how an institution might better support and attract males to use SI, a comparison of the use of social versus one-on-one forms of SI was done. At Northeastern University three types of social SI for freshman chemistry were offered (Connections Chemistry Reviews, Chem Central, and study groups); and, two types of one-on-one SI were offered (instructor/TA office hours and the COE Tutoring Office). These forms of SI were available to both female and male students and used by both genders. In order to explore the effects of socialization on gendered use of SI,
several tests were performed (Figure 7). Using a one-sample one-tailed t-test, it was determined that females who found studying in groups useful had a higher GPA after their first semester in college than females who did not, supporting the hypothesis that females’ use of this social form of SI increased their academic success. It then was hypothesized that males would rate one-on-one forms of SI higher than females. Conversely, using a two-sample one-tailed t-test it was found that females found one-on-one forms of SI more useful than males on average. These outcomes supported the observed tendency of females to feel more positively about SI and contradict the argument that the type of SI is influential in the attitudes of each gender toward the resource offered.

![Figure 7: Comparison of first semester GPA between males, females, and females who used group studying, a social form of SI (left). Comparison of males’ and females’ ratings of one-on-one forms of SI (right).](image)

**Figure 7: Comparison of first semester GPA between males, females, and females who used group studying, a social form of SI (left). Comparison of males’ and females’ ratings of one-on-one forms of SI (right).**

**Conclusions**

This study used statistical analysis to examine correlations among freshman engineering students’ grades in a required chemistry course, their subsequent academic performance on their path towards graduation, their use of and attitudes towards SI, and their gender. From this study the following specific conclusions were drawn:
- GPA after four semesters in college was highly predictive of GPA at graduation, regardless of gender. This conclusion was based on students who enrolled as freshmen in General Chemistry for Engineers during the time period of Fall 2007-Fall 2012.
- The grade received in freshman chemistry correlated positively with a student’s subsequent GPA after four semesters, with females on average both receiving higher final grades in chemistry and having a higher GPA after four semesters than their male peers.
- Students finding SI useful were more likely to perceive that a rigorous required freshman chemistry course was easier to master than anticipated.
- The frequent use of SI in a single course taken during the first semester in college can be predictive of long-term academic success. Students regularly attending a structured peer
tutoring session, as a form of SI for a freshman chemistry course, were more likely to have a higher GPA at graduation than their peers who were infrequent attendees, regardless of gender.

- Attitudes towards SI correlated positively with academic outcomes. When offered multiple forms of SI for freshman chemistry, including social and one-on-one SI, females were more likely to find one or more of these resources helpful, much more likely to attend structured reviews led by upper-level females who could act as role models, and rate one-on-one tutoring more helpful than their male peers.

This study suggests that the willingness of female engineering students compared to their male peers at Northeastern University to engage in SI as freshmen enrolled in General Chemistry for Engineers may lead to their higher grades in the course in the short-term and their higher GPA as they progress through the engineering curriculum in the various sub-disciplines for engineering in the longer-term. Does the use of SI increase their confidence and help develop strategies that can be applied next semester? Research for this study is ongoing as more graduating GPA data is collected with subsequent class graduations. Follow-up research also is warranted to establish which specific factors in how students perceive SI have the deepest impact on their immediate grades in freshman chemistry and longer-term academic achievement as well as any correlations between the gender of the tutor, faculty instructor, or teaching assistant on the efficacy and receptiveness of a gender for SI. Questions this ongoing research seeks to address include: what specific factors at Northeastern University promote the increased use and efficacy of SI by female students; what strategies can work best to overcome preconceptions towards SI by male engineering students and promote their use; and what impact does gender of the peer tutor for weekly group reviews have on attracting participants to these reviews.

References


