SUPPORTED LEARNING GROUPS (SLGS) IN A FIRST-YEAR ENGINEERING CHEMISTRY COURSE

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Abstract – *The Engineering Undergraduate Office at the University of Waterloo first started using Supplemental Instruction (SI) in a common first-year chemistry course, ChE102, in September 2013 and continued in September 2014 and 2015. This paper shares the mechanics of how SI was implemented for 11 cohorts totaling approximately 3900 students over the past 3 fall terms. Findings suggest that students who attend SI after midterms have higher final grades in their CHE 102 course as well as a higher overall term average. As well, the academic standing of students (based on their midterm grades) can help to accurately predict which students will attend SI sessions. Similarly, attending SI after midterms can also help a certain type of student improve their marks in ChE 102 and also their term average.*

Keywords: Supplemental Instruction, Supported Learning Groups, First Year Engineering

1. INTRODUCTION

Supplemental Instruction (SI), also known as Supported Learning Groups (SLG), was originally developed by the University of Missouri-Kansas City (UMKC) as a way of supporting the learning of good study skills and course content in key courses with low success and retention rates. Data from UMKC and other institutions, largely non-Engineering, show that the addition of SLG both improve completion of key courses but also suggest the long-term success of students [1], [2], [11].

Several studies have highlighted the various benefits that students and institutions experience as a result of integrating an SI program, including higher mean grades, reduced failure rates, and higher retention and graduation rates [3], [17]. Additionally, there is evidence to suggest that SI provides benefits beyond retention and grades; for example, increased motivation and engagement, reduced anxiety, the development of deep approaches to learning [15] study strategies and problem-solving skills, an increased ability to critically review material, improved self-confidence, a more developed social network and ability to work with others [11].

The benefits of SI have also been realized in an Engineering education context. SI has been implemented to support persistence and enhance student interactivity at Engineering institutions which rely mainly on traditional education methods such as lecture, tutorial, and laboratories [2]. These social development opportunities were seen as particularly valuable for incoming students who increasingly benefit from developing a network of potential study partners to engage in active and collaborative learning. In a study on supporting persistence in barrier courses in Engineering, Bronstein [2] concluded that students enrolled in SI '*achieved better self confidence in studies, developed their way of studying, created contacts with other students, trained their ability to critically review material as well as presenting material in front of others and developed problem-solving skills and the ability to work with others*.'

Engineering education literature also notes the inclusion of SI in an effort to decrease attrition by providing at-risk and high-risk students with additional opportunities to master course material and develop effective study skills [17]. Malm, Bryngfors and Mörner [11] implemented SI in a difficult first year engineering course and found that final exam grades were higher on average for SI attendees than non-attendees.

In another example, Webster and Dee [17] integrated SI into an introductory Engineering Analysis course. A majority (66%) of attendees in this study were classified as at-risk or high-risk. They found that students who attended SI achieved higher course grades than those who did not and that attendees were less likely to receive a final grade of D or F or withdraw from Engineering. McCarthy, Smuts and Cosser [13] found improved final course grades for SI attendees in an Electrical Circuits course. They also compared the academic ability of the students as a weighted average of all courses besides the SI course and found a statistically significant difference between attendees and non-attendees, revealing that attendees tended to experience greater academic success. It was theorized that their achievement was due to their existing academic motivation, which brought them to SI in the first place, or because SI impacted their ability in their other courses; however, it was cautioned that the latter was less likely.

A student's level of preparedness or prior achievement (often conceived as cumulative GPA from secondary school, SAT scores or admissions requirements) correlates to SI attendance and academic achievement. However, the voluntary nature of the traditional SI program raises questions about whether self-selection bias is skewing these outcomes. Preszler [18 pp. 190] emphasizes '*...an alternative explanation for the higher performance of students who have chosen to participate in SI is that these students were more motivated to learn and so would have outperformed other students even if SI were not available.'* The results the cited study indicate that approximately one-third of the improvement in performance of SI students is associated with initial motivational differences, rather than the effects of SI. Similarly, the curricula, programs and experience that comprise a student's prior academic achievement are determined based on vastly disparate standards and may therefore not prove to be a reliable benchmark of a student's level of academic standing for post secondary studies [13].

In an engineering context, Webster and Dee [17] suggest that even '*students who performed well in high school classes while exerting minimal effort, may not possess the necessary study skills appropriate for a rigorous college environment*' and that *'... engineering problem solving is often a totally new mental exercise for college freshmen, even for students who excelled in high school math and science classes*.' Thus, engineering students are often entering post-secondary underprepared despite having achieved exceedingly well in high school, and therefore they may stand to benefit greatly from SI.

This paper will present a program evaluation of SI in the Faculty of Engineering at the University of Waterloo. It will examine the patterns in student's SI attendance based on their level of academic standing in their first post-secondary term in Engineering. Finally, it will identify whether SI helps to improve student grades in chemistry and the overall term average for academically underprepared students.

2. SI AT THE UNIVERSITY OF WATERLOO

The Engineering Undergraduate Office at the University of Waterloo (UWaterloo) started using SI in a common first-year chemistry course, ChE 102 – Chemistry for Engineers, in September 2013 and has continued during the subsequent fall terms. Engineering at UWaterloo is divided into eleven cohorts based on the Engineering discipline (chemical, civil, environmental and geological, and management science) with the larger disciplines having two or three cohorts (electrical and computer, mechanical, and mechatronics). The total number of students enrolled in ChE 102 each year is around 1300 for a total of 3900 students over the past three years.

2.1 The SI Leader

At Waterloo, we have modified the traditional SI Leader model. An upper-year student is hired on a co-op term as the primary SI Leader instead of a near peer on an academic term. This coop student is responsible for running SI sessions for five cohorts and the overall administration of the SI program. Three other co-op students, hired to support the first year Chemical Engineering students, are the SI Leaders for the remaining six cohorts, each responsible for two cohorts. Two one-hour SI sessions are run each week for each cohort.

Members of the First-Year Engineering office met weekly with the SI Leaders to discuss the progress of the SI sessions, what can be done to improve the sessions, how to improve attendance, and generally support the leaders.

2.2 Level of Academic Standing

The Faculty of Engineering at the University of Waterloo is consistent with the extremely high admissions standards that are common of Engineering programs. Very few, if any, students would be noted as low achieving and/or academically at-risk upon entering Waterloo Engineering. Thus, students high-school grades may not be the most reliable benchmark for identifying a student's level of academic standing in Waterloo Engineering.

As we evaluate the effectiveness of the SI program, we acknowledge that there is great value in utilizing level of preparedness as an indicator for potentially high-risk and at-risk students who may require more encouragement to access SI support. Practically, Engineering advisors use midterm grades to determine whether a student is academically at-risk. For this reason, our analyses will also use midterm grades as the benchmark of the level of academic standing for university-level Engineering courses.

2.3 Data Collection

Data were originally collected for program evaluation purposes on a SI program between Fall 2013 and Fall 2015. Data collection was carried out by a faculty member within the Faculty of Engineering who had been tracking students' participation rates in SI. In order to conduct a follow up analysis of the 'level of academic standing of students attending SI', these data were given to an individual in a central support unit containing record level student data including midterm and overall term average, ChE 102 midterm and final course grades, and students' SI attendance.

3. ANALYSIS OF THE SI PROGRAM

3.1 Preliminary Analysis

A preliminary analysis of SI effectiveness at Waterloo was conducted. The SI data showed that ChE 102 fail rates have consistently decreased from 2013 to 2015 as noted in Table 1. Although the course averages stayed relatively the same, the standard deviation also decreased each year, indicating that low marks were being shifted upwards and high marks may have been shifted downwards.

Table 1. Yearly averages, standard deviations, and the change in the fail rates for ChE 102 prior to SI implementation.

Year	Average	Standard Deviation	Change in Fail Rate (%)
2013	72	16	-2.2
2014	72	15	-3.5
2015	71	14	-3.8

These findings led to a further analysis on the data from 2015 to see if statistically significant conclusions could be drawn between SI attendance and ChE 102 grades and/or SI attendance and overall term average. The fall of 2015 was chosen due to higher attendance rates compared to the previous years as noted in Table 2.

Table 2. SI Attendance

Year	Number Enrolled	Number Attended SI	% Attended
2013	1239	489	39
2014	1209	277	23
2015	1257	673	54

Using the Kruskal-Wallis H test for normality students' fall 2015 grades were compared based on their SI attendance. Based upon the analysis of these data no statistical significance could be found between student's attendance in SI before midterms and their overall average at midterms ($p=0.128$), midterm ChE 102 grade ($p=0.110$), overall term average ($p=0.927$)., or final ChE 102 grade ($p=0.568$). Therefore, the remainder of the analyses focused on exploring if there were identifiable patterns in student's SI attendance based on their academic achievement in their first post-secondary term in Engineering *after midterms.*

When exploring student participation in SI after midterms, 32.8% (n=413) of students attended 1 or more SIs. 67.2% (n=846) did not attend an SI after midterm. Based upon the analysis of these data there was a positive correlation between student's attendance in SI after midterms and their overall average at midterms ($p=.006$), midterm ChE 102 grade ($p=.012$), overall term average ($p=02$)., or final ChE 102 grade ($p=.003$). Therefore, it is suggested that attending SI programming in Engineering at Waterloo results in higher grades. These findings are consistent with much of the SI the literature, e.g., [3], [17].

3.2 Patterns in SI Attendance based on level of academic standing

To further assess which 'types' of students are benefitting from SI participation, student's ChE 102 midterm grade and overall average at midterms were used as indicators of the student's level of academic standing. Taking a similar approach to Webster and Dee (1998), students' level of academic standing were categorized as high-risk (<50%), at-risk (between 50% and 60%), satisfactory (between 60% and 70%, good (between 70% and 80%) and excellent (>80%). These categories follow the Faculty of Engineering academic standing and progression rules.

Based on student's overall average at midterms, of the 1257 students enrolled in the Fall 2015 cohort, 6.8% (n=85) of students were considered 'high-risk', 11.9% (n=150) were considered 'at-risk', 21.7% (n=273) were considered 'satisfactory', 29.9% (n=376) were considered 'good', and finally, 29.6% (n=373) were considered 'excellent'.

When identifying the same students' level of academic standing based on their ChE 102 midterm grade, 9.6% (n=121) of students were considered 'high-risk', 11.8% (n=148) were considered 'at-risk', 16,4% (n=206) were considered 'satisfactory', 20.3% (n=256) were considered 'good', and finally, 41.8% (n=526) were considered 'excellent'.

Two questions were identified to inform the 'types of students' who participate in our SI program:

1. When controlling for a student's overall average at midterms- Is there a relationship between a student's SI attendance and their overall term average?
2. When controlling for a students ChE 102 midterm grade - Is there a relationship between a student's SI attendance and their ChE 102 final grade?

To assess differences in students' level of academic standing by category, the Kruskal-Wallis H test was again used. This test was used to determine identifiable patterns in the data set based on SI Attendance. The *independent variable was* SI Attendance after midterm and the *dependent variables were* student midterm and overall term average and ChE 102 midterm and final grades (categorized by level of academic standing).

4. RESULTS

The purpose of this study was to explore if there are identifiable patterns in students' SI attendance after midterms based on their level of academic standing in their first post-secondary semester in Engineering. As well as, identifying whether SI helps to improve student grades in chemistry and the overall term average for academically underprepared students.

4.1 SI Attendance based on Midterm Average and CHE 102 midterm grade

Within the Fall 2015 cohort, 32.8% (n=413) of students attended 1 or more SIs after midterms. 67.2% (n=846) did not attend an SI after midterm. Students' midterm grades differed significantly (p=0.01) for students attending 1 or more SI session after midterms versus students who did not attend SI sessions after midterms. There was a small positive association between the variables at $r_s = 0.102$. This suggests that attending SI sessions after midterms is associated with students who had a higher level of academic standing. Similarly, students' CHE 102 midterm grade differed significantly (p=0.001) for students attending 1 or more SI session after midterms versus students who did not attend SI sessions after midterms. Again, there was a small positive association between the variables $r_s = 0.107$. Again, this suggests that attending SI sessions after midterms is associated with students who had a higher level of academic standing.

The small positive effect associated with these results also suggests that the more SIs a student attends after midterms the higher the academic standing category they will be likely be associated with – however, caution should be taken when interpreting this statement due to the small effect size (Recently there has been an effort to suggest that a "small" effect size in educational research is probably still meaningful and important to educational practice as it still shows a difference in groups of a quarter to a fifth of a standard deviation [12]. Overall, these results suggest that the patterns identified in SI attendance are not due to chance; therefore, a student's level of academic standing after midterms (based on either overall average at midterms or ChE 102 midterm grade) can be utilized reliability to assess which students are more likely to attend SI sessions after midterms.

Descriptively, patterns in the data highlight a more curvilinear relationship between SI attendance after midterms and the level of academic standing based on overall average at midterms and ChE 102 grade. 76.5% of students (n=65) who were identified in the 'High Risk' category *did not* attend SI. In comparison to 56% (n=84) of 'At Risk' students, 57.5% (n=157) of 'Satisfactory' students, 64.8%(n=257) of 'Good' students and 75.3% (n=281) of 'Excellent' students did not attend SI. When reviewing these categories based solely on CHE 102 midterm grades, patterns in the data highlight a similar curvilinear relationship between SI attendance and academic standing. With 66.9% (n=81) of 'High-Risk', 55.4% (n=82) of 'At-Risk', 61.7% (n=127) of 'Satisfactory', 66% (n=169) of 'Good' (n=385), and finally, 67.2% (n=521) of 'Excellent' students not attending SI.

4.2 SI Attendance, Overall Term Average and CHE 102 Final grade based on level of academic standing

When categorizing students based on their level of academic standing, students' Term GPAs also differed significantly (p=0.05) when 1 or more SI session were attended after midterms versus attending no SI sessions after midterms. There was also a small positive association between the variables at $r_s = 0.112$. This confirms that attending SI sessions after midterms is associated with students who had a higher level of academic standing at midterms. As well, that attending SI sessions after midterms improves students' Term GPAs.

When controlling for students' different levels of academic standing at midterms, further complimentary patterns emerged. 'High risk' students' term GPAs differed significantly (p=0.01) when 1 or more SI session were attended after midterms versus attending no SI sessions after midterms. There was also a moderate positive association between the variables at $r_s = 0.404$. This highlights that 'high risk' students who attend SI are more likely to have their grades improve than 'high risk' students who do not attend SI after midterms. Descriptively, students who were identified as 'high-risk' at midterms, and remained 'high-risk' at finals show differences in their patterns of SI attendance as well, with

93.3% (n=28) of these students not attending SI after midterms versus the 67.2% (n=846) of students in total who do not attend SI after midterms. When reviewing this ‘high-risk’ group specifically, a small sample size suggests the need for a follow up analysis to further support these findings.

Similar results were also found for students identified in the ‘satisfactory’ (p=0.05) and ‘good’(p=0.05) categories after midterms. There were also small positive associations between the variables at r_s = 0.196 and r_s = 0.174 respectively. Students’ term GPAs and SI attendance did not differ significantly for students identified in the ‘at-risk’ and ‘excellent’ categories after midterms.

When categorizing students based on their level of academic standing, students’ ChE 102 final grade did not differ significantly (p=0.05) when 1 or more SI session were attended after midterms versus attending no SI sessions after midterms. These results suggest that students SI attendance and ChE final grade do no differ significantly based on a students academic standing at midterm.

5. DISCUSSION

This study lead to several important findings to support our program evaluation purposes in the Faculty of Engineering at the University of Waterloo. First, when looking at the final Chemistry grade and the overall term average, students who attend SI after midterms achieved higher Chemistry grades and overall term average suggesting that there is value in attending SI. This is similar to the findings of a study by McCarthy et al. [13] in a Chemistry for Engineering course. They found that students who attended SI consistently throughout the term improved their final course grade while also attaining a higher weighted average of all enrolled courses for the study term. Follow up papers will be written to discuss our findings at the University of Waterloo with regards to consistent and regular attendance in SI in relation to student standing.

Second, students attended SI in a curvilinear fashion, that is, the academically strongest and weakest students attended the least, which is in line with help-seeking research. For instance, Hodges, Dochen, and Joy [6] suggest that one factor to explain the poor attendance patterns of high-risk students is that these students may have ‘*unrealistic perceptions about their own academic progress and skills and may not seek help based on false feelings of success.’* Furthermore, the trends in SI attendance for high risk students, with 93.3% of this group never accessing SI based on their overall average at midterms, seem to be in line with the suggestion that low achieving and high-risk students may lack metacognitive abilities, may be not be cognizant of their ‘incompetence’ and may lack the knowledge and self-efficacy to participate in SI [5], [10], [16]. However, there was improvement in the level of achievement for those who had the metacognitive ability and cognizance to self-select into SI participation.

While SI is not considered remedial by practitioners and researchers, due to its presence in high-risk courses, another possible explanation for the attendance trends might be that students are perceiving SI as remedial. To high risk students attending SI could imply incompetence and pose a threat to the self-worth of students who are struggling [8]. Paired with the voluntary nature of this academic support its benefits are not likely being as widely realized as they could be.

Thus, it seems unrealistic to expect high risk students to take sole responsibility in accessing supports such as SI. This is especially pertinent considering a number of confounding factors including Webster and Dee’s [17] finding that first year Engineering students are often underprepared despite excelling in high school, as well as an academic system that provides little to no direct feedback on their current level of competence and achievement before midterms, and in knowing that they are more likely to be unskilled in self-monitoring and metacognition. Handel and Fritzsche [5] suggest that in order to support low achieving students’ success, researchers and practitioners should be working to help these students to make accurate judgements of their knowledge.

However, findings of Karabenick and Knapp [9], identifies that help seeking behavior decreased to nearly zero when students expected a final grade of D or lower. Similar follow up studies have supported this finding including Karabenick [7] and Karabenick and Dembo [8]. This might suggest that even when high-risk students become more cognizant of their incompetence and lack of knowledge they may still not be likely to access academic support. The final finding of our study highlights that for high-risk students SI may help to improve their grades; however, if help seeking behavior decreases for students with low academic standings how do we support these students effectively with SI style interventions?

Several academics have proposed a mandatory SI program may improve performance and retention [6], [14]. Despite concerns that mandating SI participation could impact students’ motivation and engagement, students enrolled in mandatory SI programs have been found to perform as well as those in voluntary programs, to earn significantly higher course grades than students in the non-Sl groups and to achieve higher overall term average than students in the non-Sl groups [4], [6].

6. CONCLUSION & IMPLICATIONS

Our results suggest that there is value in attending SI consistently and regularly and that SI can benefit students in all achievement levels. However, our results also suggest that the voluntary nature of the traditional SI program is limiting some students' potential for success, particularly high-risk students who stand to benefit the most from academic support.

In Spring 2016 and Fall 2016 we will review concerns around the feasibility of expecting high-risk students to take sole responsibility for accessing supports with a pilot intervention. Considering the finding of this program evaluation and the literature that suggests that consistent and regular attendance has an impact on students' overall term average, two SI style interventions may be introduced for low achieving students in their ChE 102 course. The proposed interventions may include the following: Spring, 2016 will target students who are repeating ChE 102 and enroll them in a mandatory SI program which they will complete throughout the entire term. Fall 2016, will identify students who are struggling academically after midterm and enroll them in a mandatory SI program. Student success rates from these interventions would then be reviewed to determine the potential effectiveness of a forced SI style intervention in First-Year Engineering at Waterloo.

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