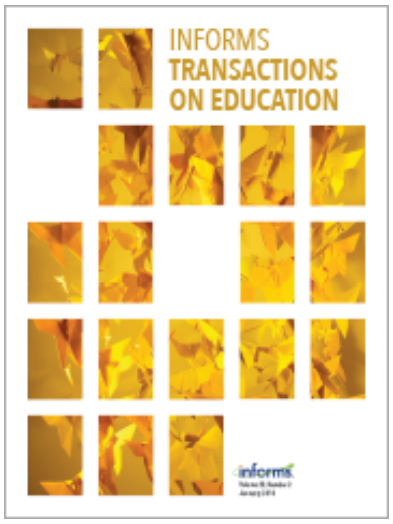

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Impact of Supplemental Instruction on Business Courses: A Statistical Study

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Abstract. Many students in quantitative business courses are struggling. One technique designed to support such students is Supplemental Instruction (SI), which is most popular in the science, technology, engineering, and mathematics (STEM) disciplines. In this paper, we show the positive impact of SI on student performance in two bottleneck business courses in a large university. Our evaluation results establish that (i) SI has a statistically significant effect on students' likelihood of passing both courses (after controlling for background variables), (ii) SI is more helpful for students identified as at risk than for those who are not, and (iii) it is important to consistently attend SI sessions for greater success. We also present models to predict consistent student attendance based on background factors with 90% accuracy and conclude with a brief qualitative study about students' self-perception of SI and the professional development attained by SI leaders.

Keywords: supplemental instruction • business courses • early detection • at-risk students • intervention techniques • background variables • student performance • student success

1. Introduction

Many studies have been undertaken to identify factors that can predict students' academic performance and success in different college-level courses, from mathematics and chemistry to engineering as well as business (Brower and Ketterhagen 2004, Herndon and Moore 2002). In particular, some courses have historically high failure rates: These are usually termed "bottleneck" courses, indicating that a large proportion of students have difficulty passing them. This, in turn, affects graduation rates in colleges and universities across the United States; some universities even report six-year graduation rates lower than 50%. As a result, many educational institutions have established programs and services aimed at increasing student retention and enhancing academic success. One such program is called Supplemental Instruction (SI), which is gaining popularity across the United States and worldwide (Malm et al. 2010, 2011).

Developed at the University of Missouri-Kansas City (UMKC), SI has been in existence for over 30 years. Research studies have documented its success in increasing retention and student performance in traditionally difficult courses (such as those in the science, technology, engineering, and mathematics (STEM) disciplines) as determined by high failure rates (typically D, F, and W letter grades when C denotes "pass") (Blanc et al. 1983, Martin and Arendale 1992). Although SI now encompasses several disciplines including arts, social sciences, and business, research studies are limited. In this paper, we present analyses and results to show the impact of SI on two bottleneck business courses at a large public university in California. We take into account several background variables, such as demographic factors (such as age, gender, ethnicity, etc.) and academic variables (such as grade point average (GPA), transfer status, etc.), to build statistical models to predict (i) the effect of SI on the probability of passing these courses, and (ii) which segments of the student population are more likely to regularly attend and benefit from SI sessions.

The remainder of the paper is organized as follows. Section 2 is an overview of SI and an extensive literature review of its effect on student performance in college-level courses. We present our research methods and hypotheses in Section 3; Section 4 introduces our data sets. Section 5 presents the results of our exploratory methods, and Section 6 provides results from the predictive models. Section 7 presents qualitative analyses of students' self-perception of the program. We conclude with a discussion in Section 8.

2. Literature Overview of SI

The level of success students achieve in college influences their academic self-esteem, persistence in elected majors, and perseverance in higher education,

among other factors. Students' success in early college semesters and their experience in introductory college courses also impacts their postcollege experiences, career choice, personal income, and the degree and nature of participation in community life. However, dissatisfaction with and low performance in introductory college classes is a serious problem at colleges and universities nationwide (Horn et al. 2002, Horn and Premo 1995). For more than two decades, research has shown that students' success in STEM disciplines is most negatively affected by their lack of success in the gateway courses that develop essential skills and introduce students to disciplinary studies (Tobias 1990, Seymour and Hewitt 1997). The problem is particularly evident in introductory mathematics and science courses. Such courses are often required and are integral components of an undergraduate education, yet many students achieve moderate or low levels of success in these courses. This often results in significant attrition of talented students (Gainen 1995; Congress of the United States Office of Technology Assessment, 1998).

With an increased focus at institutions of higher education on increasing retention and improving graduation rates, many colleges and universities are examining ways to improve student performance and success in specific courses as well as in degree programs. Toward this end, they are introducing academic development and support programs to provide students with additional help to enhance their understanding of course materials and succeed in difficult courses. Among such programs, one now being widely used is SI, which was developed at the University of Missouri-Kansas City (UMKC) by Deanna Martin in 1972 (Arendale 2001). It offers voluntary, scheduled, peer-led sessions outside of regular class time and is open to all enrolled students within a course. SI does not target remedial students or identify students who are academically at risk of not succeeding in college. It relies on participation in small group interactions (called SI sessions) facilitated by an SI leader who is also a student who has already successfully completed the course for which SI is offered (Dawson et al. 2014).

Research studies have shown that SI is effective in improving the academic performance of participating students (Malm et al. 2010, 2011; Ogden et al. 2003). Moreover, SI significantly enhances reasoning and problem-solving skills (Shaya et al. 1993) as well as increasing retention (Lyle and Robinson 2003), GPA (Fayowski and MacMillan 2008), and graduation rates (Bowles et al. 2008, Congos 2003), specifically in STEM-related fields (Peters et al. 2007). In addition, SI provides students the training necessary to learn and assimilate the study skills that will help them in later semesters (Fayowski and MacMillan 2008, Peters et al. 2007). Congos (2003) also reported that SI participants tend to persist and re-enroll in classes at a higher rate than those who do not participate in SI. In fact, the success of this program led the United States Department of Education to designate it as an "*Exemplary Educational Program*" in 1981 (Burmeister 1996, Widmar 1994, Blanc et al. 1983), which precipitated widespread dissemination throughout the country.

Although SI is known to benefit all students, existing studies show that it provides significant benefits to ethnic minorities . Such students participate more in SI than ethnic nonminority students, and earn one half of a letter grade higher than nonparticipating minority students (Wilcox and Koehler 1996). These improvements have been shown to be statistically significant compared to those achieved by students belonging to other ethnic groups. This is particularly important for colleges and universities that enroll a large number of underrepresented students. Rabitoy et al. (2015) evaluated demographic and academic preparation variables of students in a community college to predict the success attained by participating in SI in STEM courses. The findings showed a differential impact of SI outcome on students based on gender and ethnicity. Bonsangue et al. (2014) showed that SI had a significantly higher impact on the performance of transfer students at a public university in college-level algebra courses than students who started as freshmen at that university.

Considerable literature also exists on discipline-specific outcomes for courses that include SI. Bridgham and Scarborough (1992) found that SI increased the final course grades for students in medical school. Commander et al. (1996) reported that students attending three or more SI sessions for an algebra course during a semester earned one-half to one full letter grade higher than students who did not. The impact of SI is more significant in science courses such as biology (Moore and LeDee 2006) and chemistry (Gattis 2002). Burmeister (1996) found higher course grades for students participating in SI for several different mathematics courses, such as algebra, calculus, and statistics. Ashburn (2006) found similar results for remedial mathematics courses as well. Likewise, McCarthy et al. (1997) found significantly higher grades for SI attendees in an engineering course at the University of Witwatersrand, South Africa. Murray (2006) reported clear improvement for students attending SI for an engineering course at Queensland University of Technology in Australia; the improvement was independent of high school performance.

Despite the extensive research on the effect of SI for STEM-related courses, research on the impact of SI in business courses remains limited. The deployment of SI in the business discipline is also not as widespread yet, although it started more than two decades ago. In a review article, Arendale (2001) noted the effectiveness

of SI offered for business courses between 1982 and 1996. Kenney (1989) and Kenney and Kallison (1994) conducted several studies that demonstrated the effectiveness of SI in first-semester calculus classes (traditionally considered difficult) for business and economics majors at the University of Texas at Austin. Jones (2013) used chi-square analysis and the analysis of covariance (ANCOVA) to study the effect of SI in an introductory accounting course and observed significantly better performance in terms of final total scores for participating students. SI is also being implemented in several business courses in other institutions nationwide; some of these include business mathematics, business statistics, finance, and managerial accounting.

Although the impacts of SI on student performance and success have been widely studied and documented, little evidence exists in the literature about its impact on the SI leaders. According to Lockie and Van Lanen (2008), SI leaders reported improved leadership skills, communication skills and self-confidence as a result of their SI experience. Additionally, Stout and McDaniel (2006) stated that leaders report overall personal, academic, and professional development. In his study, Zaritsky (2006) found that 98% of SI leaders reported that their role as an SI leader helped them gain self-confidence and strengthened their leadership skills.

3. Research Design and Hypotheses

In this study, we investigate the impact of SI on two bottleneck courses in the College of Business at a large public university. These courses form a sequence: The first is a course on Business Statistics; the second is on Management Science. Both are considered "core" courses that must be completed by every student pursuing an undergraduate degree in Business Administration. The first course is a prerequisite for the second.

Our study consisted of quantitative and qualitative analyses. First, we conducted exploratory analyses based on descriptive statistics and statistical hypothesis tests (e.g., t-tests, ANOVA) to form an initial understanding of the data. Next, we built predictive models based on *logistic regression* (Hosmer and Lemeshow 2000) to study the following:

1. *The impact of SI on student performance:* determining the effect of attending SI and the number of SI sessions attended on student performance (as measured by final percentage grades) and the probability or chance of students passing the course with a letter grade of C or above. This helped us investigate the success of the SI program in assisting students to improve their performance and pass these bottleneck courses in the business discipline and further understand the effect of the different number of sessions attended.

2. *Predict the highest benefit from SI:* investigating which students benefit the most from the SI program (in terms of achieving the maximum improved likelihood of passing). In particular, we explored the amount of improvement attained by low performing students or those at risk of failing the course based on certain background academic factors. The following research hypothesis was therefore of interest:

Hypothesis 1 (H1). *Students who are found to be low performing achieve significantly greater improvement from attending more SI sessions than those who are not.*

3. *Predict "consistent" participation in SI:* determining which students (based on background variables) are more likely to attend eight or more SI sessions during a semester. We chose this number because there are typically few students who attend more than eight SI sessions during the semester (less than 1%). This was helpful from a logistical and planning perspective to determine the number of SI sessions to be offered in a particular semester as well as to find out which students consistently require more encouragement and motivation to participate in SI. The following research hypothesis was thus of interest:

Hypothesis 2 (H2). *Students who have attended SI sessions previously (e.g., in another course) are more likely to consistently participate in SI, that is, to attend more than a certain number of sessions.*

We used statistical models to test whether the evidence in our data supported these two hypotheses. The first hypothesis helped establish the efficacy of the SI program in helping students who need additional support to succeed in these courses. The second hypothesis helped determine which subgroups of students are more likely to consistently participate in SI.

Finally, we performed qualitative analysis of data obtained via student surveys to assess their self-perception of overall satisfaction and benefits attained from SI, as well as surveys conducted among SI leaders to assess their professional development as part of the SI program.

4. Data

SI was first implemented in the business curriculum for Business Statistics and Management Science courses in Spring 2014 as a pilot program. Every semester it is offered to roughly 10–12 sections for each course, thus catering to 400–600 students. The total enrollment for each course is about 1,000–1,300 per semester. We collected data from these two courses for two subsequent semesters, i.e., Fall 2014 and Spring 2015 (data from Spring 2014 are not used in the study, as pilots often suffer from unforeseen issues). Data collected were as follows:

- SI attendance, i.e., which students attended, and how many sessions were attended by each student (data from SI leaders)

- Students' midterm and final grades (in percentage form as well as letter grades), collected from course instructors

Apart from these, several background variables were also collected from the campus office of Institutional Research and Analytical Studies. These included:

- *Demographic variables*, i.e., age, gender, ethnicity, and first-generation status (many students on our campus are first-generation college attendees)
- *Academic variables:* GPA, transfer status (whether students transferred to our university from a local community college or started as freshman), grades from a prerequisite course that must be successfully completed before taking these business courses, the number of units of classes enrolled in during the semester, the number of attempts at the course (this shows whether a student is repeating), and academic status (such as disqualified, on probation, etc.)

All of these variables were used to study the effect of SI on different subgroups of the student population as well to determine which students consistently attended and benefitted from SI sessions.

5. Exploratory Analysis and Results

First, we present some initial exploratory analyses based on descriptive statistics and statistical hypothesis tests. These provide some insight into the data that helped us develop our predictive models.

5.1. Demographic and Academic Background

Table 1 provides a brief summary of the key features of the demographic and academic background of our student population that was part of this study. A fairly uniform pattern was seen every semester; hence, we report the averages over the two semesters. Both courses were dominated by Asian/Pacific Islanders followed by Caucasians and Hispanics, a fairly accurate representation of the composition of our overall student body in the College of Business. Moreover, nearly 32% of students are first in their family to attend college. The average age of students in both courses is 20 and 24.

In terms of their academic background, the majority of students in the two courses were transfer students, i.e., they transferred to our university from a local community college; the rest started as freshmen. The average GPA of students taking the Business Statistics course over the two semesters is 2.85 (of a maximum of 4), whereas that for the Management Science course was 2.77. Many students repeated both courses, with about 7% repeating more than twice. Moreover, every semester 2%–3% of students were academically disqualified or put on probation. These statistics, coupled with the fact that these courses have high failure rates of around 20% ("bottleneck"), clearly demonstrated the need to devise intervention and support programs for all students who have difficulty in these courses.

Table 1. Background Variables Students in the Two Courses (Averaged Over Two Semesters)

	Business statistics (%)	Management science (%)
Gender: Men	56	59
Ethnicity: Hispanic	29	27
Asian/Pacific islander	30	31
Caucasians	24	26
Transfer status: Transfer	65	63
# of earlier attempts: 1	12	11
2 or more	7	6

5.2. SI

Over two semesters, the overall participation rate for SI was 17.9% (Business Statistics course) and 32.9% (Management Science course). Because both these numbers were lower than desired , particularly for the Business Statistics course, we have sought to expand and improve this new initiative to increase attendance. Furthermore, many students lack sufficient flexibility in their daily routines between school and work to attend these extra sessions; hence, we are exploring opportunities to offer SI sessions in the evenings, on weekends, and in an online format to accommodate more students.

Table 2 shows the failure rates (as measured by the proportion of students obtaining D, F, and W grades) in the two courses, broken down by whether they attended at least two SI sessions in the two semesters. We see that a significantly lower number of students attending SI sessions failed the course than those who did not attend; this pattern was uniform across the two courses and the two semesters under study. Statistical tests also revealed significant p-values (<0.0001), leading to the conclusion that, overall, SI had a positive impact on students' success rates in these two business courses, as seen over two semesters. Another noteworthy observation is that no student who attended SI dropped out of the course (except one in Spring 2015 for Business Statistics). This is important because 2%–4% of students drop these courses in the middle of the semester, and must retake them. One of our goals is to reduce this phenomenon while also reducing failure rates.

Previous research has shown that not only does SI attendance have an impact on student performance but also the number of SI sessions that students attend. To study this, we looked at students' average final percentage grades (Table 3), which show that the performance of students attending at least 10 SI sessions was significantly better than those who attended fewer sessions; this was consistent across the two courses and over the two semesters. ANOVA also revealed statistically significant differences for three of these four cases

Table 2. Failure Rates of Students in the Two Courses Who Attended SI (Row 1) and Who Did Not Attend SI (Row 2)

For students who:	Bus. stat. (Fall 2014)	Bus. stat. (Spring 2015)	Man. sci. (Fall 2014)	Man. sci. (Spring 2015)
Attended SI	11.2% ($n = 98$)	12.2% ($n = 77$)	6.9% ($n = 146$)	8% ($n = 161$)
Did not attend SI	21.4% ($n = 333$)	17.3% ($n = 422$)	15.5% ($n = 308$)	12% ($n = 439$)

(leaving out Business Statistics in Fall 2014). Moreover, only two or fewer students who attended 10 or more SI sessions during a semester failed the course, which is significantly lower than the overall failure rates in these two courses. Of those students who attended 1–9 SI sessions, about 5–10 failed every semester; this number decreased as students attended more SI sessions.

5.2.1. Academic Background of Students Who Attended SI. A pertinent question often asked about SI is: *Do only academically strong students attend SI sessions, hence leading to high grades for SI attendees?* This is because SI sessions are typically voluntary and based on student self-selection. However, studying the GPA of students at the beginning of each semester did not reveal any statistically significant difference between the prior academic performance of students attending and not attending SI sessions. Similarly looking at students' pre-requisite course grades, number of attempts, and academic status, no significant differences were observed between groups of students who attended and did not attend SI for these two business courses.

5.2.2. Which Students Benefitted Most from SI? Although we see overall improvement in student performance from attending SI sessions, certain groups of students may benefit more, that is, achieve greater improvement than others. In this subsection, we use demographic and academic data collected from students to study this. Our analyses revealed very similar trends across the two courses and the two semesters. Below is a summary of our observations.

- *Groups of students who benefitted most from SI* include transfer students, those who were on probation or academically disqualified, those who had attempted the course more than twice earlier, and those with a high GPA (>2.80) but low Midterm grades (<70%). The last group are academically strong but were not doing well in the course at the beginning of the semester. Mitra and Goldstein (2015) established the efficacy of intervention methods that detect at-risk students based on prior academic record, such as GPA. Such students benefit significantly more from consistently attending SI sessions than students who were not identified as being at risk.
- *Factors not affecting the amount of improvement from SI:* Gender, age, first-generational status, and the number of units of classes in which students enrolled.

These observations show the importance of studying the effect of SI on different student subgroups pursuing an undergraduate degree in Business Administration. This can help develop targeted intervention techniques for such students so as to maximize the benefits of SI. We use these insights to develop our predictive models in the next section.

6. Predictive Models

We present two types of predictive models that help us to study the following aspects of SI:

- *The effectiveness of SI*: These models study the effect of SI participation, including the number of sessions attended, on the probability of passing the course, while controlling for other background variables. The latter help us understand which other characteristics of the student population are likely to contribute to a student's chances of passing this course. Another aspect that we investigate in this context is the effectiveness of SI in improving performance of at-risk students with respect to failing the course, as discussed in the previous section.
- *Participation in SI*: These models predict which students are likely to consistently attend SI sessions (i.e., more than eight sessions). Our data show that very few students attend 10 or more SI sessions during a semester, hence eight sessions were chosen as the optimal threshold to ensure that we had a reasonable sample size to develop our model for SI participation. This model is important, as we saw earlier that the full benefits of SI are usually realized with regular attendance.

Table 3. Average Final Percentage Grades of Students Who Attended Different Numbers of SI Sessions (Rows 1–3)

No. of SI sessions	Bus. stat. (Fall 2014)	Business statistics (Spring 2015)	Management science (Fall 2014)	Management science (Spring 2015)
None	75.21% ($n = 333$)	76.73% ($n = 422$)	75.76% ($n = 308$)	78.3% ($n = 439$)
1–9	78.26% ($n = 67$)	74.3% ($n = 52$)	79.17% ($n = 96$)	76.56% ($n = 109$)
≥ 10	79.27% ($n = 31$)	86.63% ($n = 25$)	80.79% ($n = 50$)	82.77% ($n = 52$)

Moreover, knowing the approximate participation rate from the prediction models can help university administrators plan resource allocation by determining the number of SI sessions to offer during a semester and the number of SI leaders to hire.

Because we wanted to estimate the probability of an event in each of the cases (passing, participation), all models are based on logistic regression. Our preliminary descriptive analyses showed considerable uniformity of results across semesters, so we combined the data from the two semesters and presented the best models obtained for each course based on accuracy metrics such as Akaike's Information Criterion (AIC) values (Akaike 1985).

6.1. Models: Effectiveness of SI

For the model to study the effect of the number of SI sessions on the probability of a student passing the course, the target or dependent variable (Y) was defined as:

$$\begin{aligned} Y &= 1, \quad \text{if a student passes the course} \\ &= 0, \quad \text{if the student fails the course.} \end{aligned}$$

The independent variables used in the model for the Business Statistics course were: *GPA*; *Attempts* = number of attempts in the course; *Units* = number of units of classes a student enrolled in during a semester; 1st *Gen* = first-generational status (1, if the student is a first-generation college attendee and 0 otherwise); *Ethnicity* (1 if the student belongs to a minority ethnic group, and 0 otherwise); *Transfer* = transfer status (1 if the student transferred to our university from a community college and 0 if he/she started as a freshman); *SI Sessions* = number of SI sessions a student attended during the semester; *Gender* = 1 if male, and 0 if female.

The model was constructed based on 2,225 data records from the two semesters. Note that here we also included those students who did not have an SI session associated with their course sections (they fall in the category of "0 SI sessions attended"), thus using all the available data. The fitted model with estimated coefficients, odds, and p-values is shown in Table 4.

The number of SI sessions was significant (i.e., a low p-value of 0.0023), which shows that the more sessions a student attends, the more his or her probability of passing the course significantly improves. The coefficient value of 0.1107 implies that a student's odds of passing the course (defined as $P(Y = 1)/P(Y = 0)$) multiplicatively increased by a factor of 0.1107 for each additional SI session attended while controlling for other background variables. Moreover, gender, the number of units a student enrolls in during the semester, and the number of attempts in the course did not have a significant effect on a student's probability of passing. Although we previously observed that students who repeated the course achieved greater improvement in performance upon attending SI than those who did not repeat, that did not necessarily translate to a significantly higher chance of passing the course. Among some of the other predictors that had a significant impact on a student's probability of passing, GPA had a positive effect; this implies that students with a higher GPA had a higher probability of passing the course (as expected). Transfer students and first-generation college students, on the other hand, had a lower probability of passing the course. Consequently, increasing intervention within these groups should yield positive results, as participation in the SI session is found to be useful.

For the Management Science course, we used a similar logistic regression model with the same predictor variables and added a new one *"PreReq"* denoting students' performance in the pre-requisite Business Statistics course. This model was based on 1,613 data records from the two semesters. The fitted model with coefficients, odds, and p-values is shown in Table 5.

The number of SI sessions attended again has a significant impact on the probability of passing the Management Science course , while controlling for several demographic and academic factors. As before, GPA remained a very strong predictor, along with the number of units of classes a student enrolled in during the semester and the pre-requisite course grade. Unlike the Business Statistics course , none of the other predictor variables were found to significantly affect the chances of passing. Specifically, the transfer status of a student ceased to function as a significant predictor of success in the course. This finding can be explained by the longer school history of a student when taking

Table 4. Logistic Regression Output to Study the Effect of SI on Student Performance for the Business Statistics Course

Variable	Intercept	GPA	Attempts	Units	1st Gen	Ethnicity	Transfer	SI sessions	Gender
Coefficient	−1.328	1.1534	0.0562	0.0054	0.3009	0.4626	0.4032	0.1107	0.1134
Odds Ratio	—	3.169	1.0578	1.0054	0.7402	0.6297	0.6682	1.1171	0.8928
95% Lower Limit	—	2.5717	0.8344	0.961	0.5752	0.4986	0.5208	1.0403	0.7114
95% Upper Limit	—	3.905	1.341	1.0519	0.9525	0.7952	0.8573	1.1994	1.1205
P-value	**<0.0001**	**<0.0001**	0.6422	0.8144	**0.0194**	**0.0001**	**0.0015**	**0.0023**	0.328

Note. The bold p-values denote the significant variables.

Table 5. Logistic Regression Output to Study the Effect of SI on Student Performance for the Management Science Course

Variable	Intercept	GPA	Attempts	Units	1st Gen	Transfer	SI sessions	Gender	PreReq
Coefficient	−2.1267	1.2407	−0.1462	0.0624	−0.2248	0.1098	0.116	0.1178	0.4555
Odds Ratio	—	3.3357	0.864	1.0644	0.7987	1.116	1.123	1.125	1.577
95% Lower Limit	—	2.2061	0.6414	1.006	0.575	0.7975	1.0474	0.7981	1.1085
95% Upper Limit	—	5.0437	1.1639	1.1263	1.1093	1.5617	1.2041	1.5858	2.2434
P-value	**0.0032**	**<0.0001**	0.152	**0.0303**	0.1798	0.5222	**0.0011**	0.1798	**0.0113**

Note. The bold p-values denote the significant variables.

this course (as the Management Science course follows the Business Statistics course), although performance improved significantly more than nontransfer students upon attending SI sessions (as seen in 5.2.2).

6.1.1. Effectiveness of SI for At-Risk Students. Of special interest to us is the effect of the number of SI sessions attended on the likelihood of passing for those students who were identified as being at a greater risk of failing each of the two courses. Note that SI sessions are open to all students; students can participate regardless of whether they are classified as at-risk. However, these analyses provide valuable insights on the advantages of SI.

The predictor variables used in the models, after comparison with competitive models with different subsets of background variables, were (i) a binary variable denoting whether a student is identified as at-risk (labeled "1") or not (labeled "0"); and (ii) the number of SI sessions attended. All other background variables included in the previous models were shown to be nonsignificant, which implied the strength of these two variables. These models had the lowest *AIC* values of 917.6 and 1,260.3, respectively.

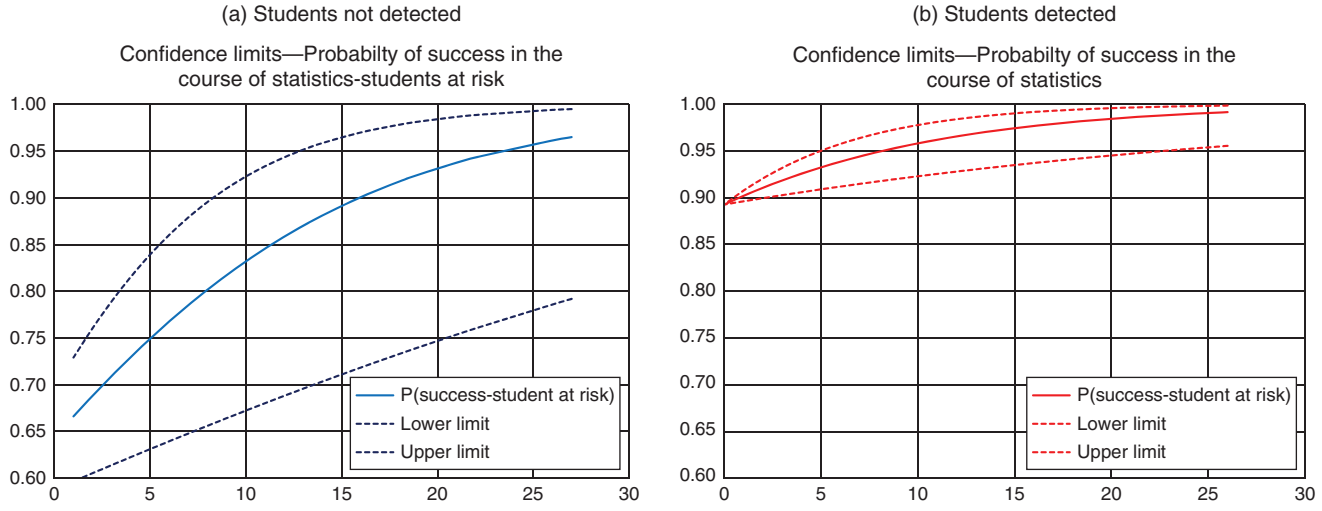
The model for the Business Statistics course is:

$$\text{Prob}(pass) = \frac{e^{2.1181-1.5281\times Detected+0.1010\times SI\ sessions}}{1+e^{2.1181-1.5281\times Detected+0.1010\times SI\ sessions}}$$

The p-values for the variables were: (1) Detected: <0.0001 and (2) SI sessions = 0.0022. Such low p-values show that both variables had a significant impact on the probability of passing. The negative value of the estimated coefficient for "Detected" clearly showed that the probability of passing the course for at-risk students was significantly lower than for students who did not attend the same number of SI sessions. Note that the interaction term was not found to be statistically significant and hence was not included in the final model.

Although SI sessions contributed to the chances of successfully passing the course for both groups (at-risk and not at-risk), the marginal improvement diminished as the number of sessions increased (i.e., most of the benefit of SI occurs at the lower end of the range of the number sessions and stabilizes for more). The plot depicting the 95% confidence intervals of this probability as a function of the number of SI sessions attended is shown in Figure 1, separately for the at-risk and not

Figure 1. 95% Confidence Intervals for the Probability of Passing the Business Statistics Course for Students Identified As (a), and Not Identified As (b), Being At Risk of Failing



Note. The solid lines represent the estimated probability.

at-risk students. The graph demonstrates the increasing effectiveness of participation in SI sessions that is predicted or expected based on the above theoretical model; this is clearly different for the two groups and significantly more for at-risk students as explained below. For instance, an at-risk student had approximately a 64% probability of passing the Business Statistics course when attending no SI session, but that probability increased to 83% when attending 10 SI sessions and 93% when attending 20 SI sessions during the semester (a 45% relative improvement). On the other hand, a student who was not identified as at-risk had an 89% probability of passing the course, which increased to 96% and 98%, respectively, if the student attended 10 or 20 SI sessions (a 10% relative improvement).

The model for the Management Science course is:

$$\text{Prob}(pass) = \frac{e^{2.9731-1.6985\times Detected+0.0637\times SI\ sessions}}{1+e^{2.9731-1.6985\times Detected+0.0637\times SI\ sessions}}$$

The p-values obtained were: (1) Detected: <0.0001 and (2) SI sessions = 0.0384. The conclusions from this model were similar to those from the Business Statistics course. The 95% confidence intervals for the probabilities of passing for students who were and were not identified as at risk (Figure 2) were similar for the two groups. In particular, we saw that an at-risk student had approximately a 78% probability of passing this course when attending no SI session, but that probability increased to 87% when attending 10 SI sessions, and to 93% when attending 20 SI sessions during the semester (a 19% relative improvement). On the other hand, a student who was not identified as at risk had a 95% probability of passing the course, which increased to 97% and 99%, respectively, if that student attended 10 or 20 SI sessions (a 4% relative improvement).

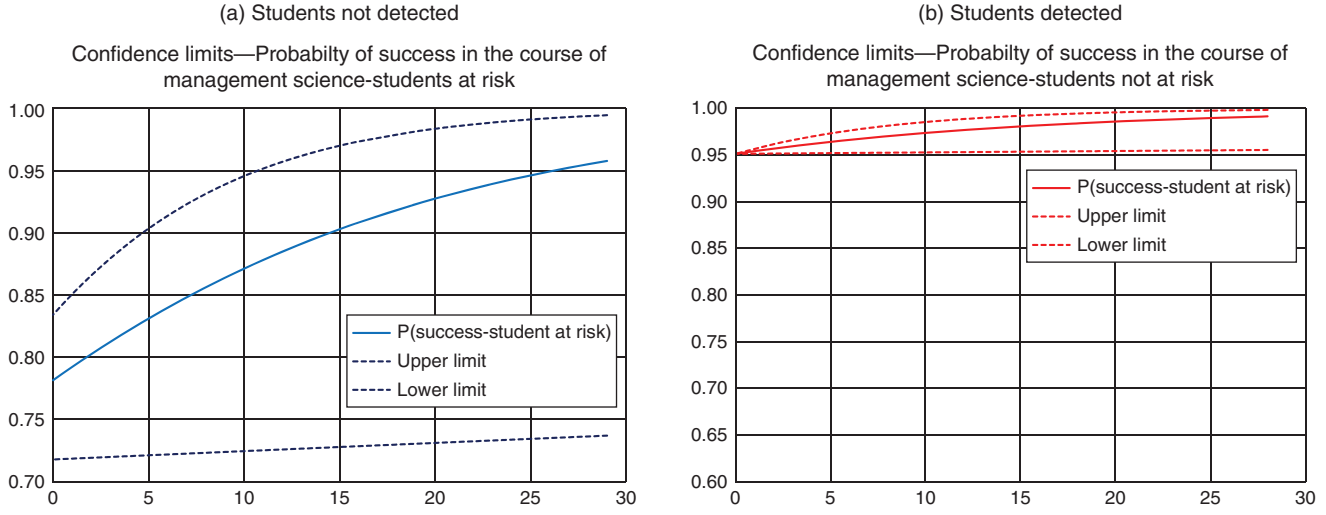
Thus, based on these results that corroborate those presented in Section 5.2.2, we conclude that at-risk students benefitted more, that is, achieved greater improvement, from attending more SI sessions than students who were not at risk. We henceforth accept the research Hypothesis H1 and conclude *that the data provides evidence to support the claim that at-risk students benefit more from attending SI sessions; in fact, their improvement increases with the number of SI sessions attended.*

6.2. Models: SI Participation

Thus far we have seen that the number of SI sessions astudent attends has a significant impact on performance in both courses. In other words, merely attending 1–2 sessions may not be sufficient to fully reap the benefits of SI. So it is important to understand which students are more likely to consistently participate in SI, i.e., to attend more than a specified number of sessions during the entire semester (we fixed this number as 8, as mentioned earlier). The predictive models proposed in this section enabled us to accomplish this, which in turn helped us encourage students who are expected to attend only few sessions to attend more. Moreover, knowing in advance (e.g., before the start of the semester) the number of students expected to use SI resources can facilitate planning and logistics. This would mean knowing the approximate number of SI leaders to hire (and hence their salary budgets), the number of sessions to offer, the amount of space to be reserved for SI during each week, etc.

To check the validity of our predictive models, we built the model based on data from Fall 2014 (training set) and tested on data from Spring 2015 (validation

Figure 2. 95% Confidence Intervals for the Probabilities of Passing for Students Identified (a) And Not Identified (b) as Being At Risk of Failing the Management Science Course



Note. The bold line represents the estimated probability.

set). The target or outcome variable (Y) for the logistic regression model was defined as follows:

$Y = 1$, if a student attended at least eight SI sessions in a semester;
$= 0$, if a student attended fewer than eight SI sessions in a semester.

Business Statistics Course. The first model we fitted consisted of all the background variables previously used in the models to study the effectiveness of SI, with the addition of one new variable, "SR" (a binary variable that takes the value 1 if the student is a Senior, and 0, otherwise). Based on the logistic regression model output shown in Table 6, the variables that had a significant effect on the probability of students consistently attending SI were transfer status and SR. The nature of the coefficients shows that seniors, and non-transfer students, i.e., those who started as freshmen at our university, were significantly more likely to consistently attend SI sessions during a semester.

Our final SI participation model using only the two significant predictors from above was:

$$\text{Prob}(Y{=}1) = \frac{e^{-2.9035-0.4956\times Transfer+0.4862\times SR}}{1+e^{-2.9035-0.4956\times Transfer+0.4862\times SR}}$$

As with any prediction model, we compared the AIC values of models to choose the best predictive model. The bigger model was the best compared to the others, with an AIC value of 672, whereas our final chosen model had the smallest AIC value of 669.

Management Science Course. The output for the best model to predict consistent SI participation for the Management Science course is shown in Table 7. Compared to the Business Statistics course, we used two additional variables, i.e., the grade in the Business Statistics course ("PreReq") that was also used for earlier models (Table 5) and the number of SI sessions attended for the pre-requisite course ("PreReq SI"). Note that the latter variable is only relevant in the context of participation; hence, it was not included in the earlier models. Moreover, we did not have data on this variable for the Business Statistics course, as that pre-requisite is in a different discipline (Mathematics) and students often complete it before being admitted to our university. The variables that turned out to be significant are transfer status and the number of pre-requisite SI sessions attended. Unlike the earlier course, transfer students were found to be more likely to attend more SI sessions, and students who had attended more SI sessions for the pre-requisite course were found to be more likely to consistently attend SI for the Management Science course (lowest p-value).

The final model with only the two significant predictors is given by:

$$\text{Prob}(Participate) = \frac{e^{-2.3191+0.6107\times Transfer+1.5066\times Pre\text{-}reqSI}}{1+e^{-2.3191+0.6107\times Transfer+1.5066\times Pre\text{-}reqSI}}$$

This model had the smallest AIC value of 627 among all the competitive models; hence, it was chosen to generate the predictions. *The results also support our research Hypothesis* H2 *that students who have attended SI before for another course are significantly more likely to attend SI sessions for a current course.*

6.2.1. Prediction Results. The model for the Business Statistics course was trained on 1,206 data records from Fall 2014 and tested on 1,042 data records from Spring 2015. On the other hand, the model for the Management Science course was trained using 900 records from Fall 2014 and tested on 435 records in Spring 2015 (restricted only to students with access to SI sessions for the pre-requisite Business Statistics course for which SI was piloted for a few sections only in Spring 2014). For both courses, subsets of the validation set were also used to estimate the margin of error for predictions (sizes of 500 and 200, respectively, for the two

Table 6. Model Output to Predict SI Participation for the Business Statistics Course

Variable	Attmpts	Units	Ethnicity	1st gen	Gender	GPA	Transfer	SR
Coefficient	−0.1080	−0.0053	−0.0852	−0.1215	−0.2862	−0.2195	−0.4623	0.4538
Odds Ratio	0.8976	0.9947	0.9183	0.8856	0.7511	0.8029	0.6299	1.5743
95% Lower Limit	0.5603	0.9111	0.5701	0.5489	0.4903	0.5093	0.3970	0.9799
95% Upper Limit	1.4380	1.0861	1.4793	1.4290	1.1508	1.2658	0.9992	2.5292
P-value	0.6533	0.9063	0.7262	0.6168	0.1886	0.3446	**0.0496**	**0.0606**

Table 7. Model Output to Predict SI Participation for the Management Science Course

Variable	Ethnicity	1st gen	Attempts	Units	PreReq	Transfer	PreReq SI
Coefficient	0.1495	−0.0196	−0.2250	−0.0592	−0.0683	0.5793	1.5178
Odds Ratio	1.1612	0.9806	0.7985	0.9426	0.9339	1.7847	4.5621
95% Lower Limit	0.7582	0.6510	0.2871	0.8762	0.6460	1.1709	2.9557
95% Upper Limit	1.7785	1.4769	2.2212	1.0139	1.3503	2.7204	7.0415
P-value	0.4919	0.9251	0.6664	0.1122	0.7163	**0.0071**	**0.0000**

Table 8. Prediction Results for Consistent SI Participation for the Two Courses

Course	Predicted participation	Actual participation	Error
Business statistics	28 ± 2.1	25	3
Management science	56 ± 1.7	52	4
Total	84	77	7 (9.1%)

courses); the final errors were obtained as the average over these repetitions (20 in each case).

The predicted numbers were very close to actual attendance, as shown in Table 8, i.e., approximately 6% within the actual value for the Management Science course and within 12% of the actual value for the Business Statistics course, thus giving an overall error of around 9%. The low standard errors also established the stability of our results. The prediction was more accurate for the Management Science course, showing that the number of pre-requisite SI sessions attended was a very powerful predictor. Although these were preliminary results, they were promising and offered key insight into student behavior with respect to SI attendance. We hope to generate more predictions for future semesters and to continue to refine and validate our proposed models.

7. Qualitative Analyses: Student Surveys

Although our analyses and results so far have demonstrated the effectiveness and benefits of SI for various groups of students taking two of the bottleneck business courses, it is important to understand students' perceptions about SI and the associated benefits. For this reason, we conducted surveys among the students to perform a qualitative study. These surveys were administered only to students who attended SI sessions. The response rates are shown in Table 9.

Table 9. Student Response Rates to SI Surveys

	Business statistics	Management science	Total
Spring 2015	165 (40%)	247 (60%)	412
Fall 2014	212 (54.5%)	177 (45.5%)	389

Students were asked to express their perceptions about how SI helped them improve the following in the context of the course:

- *Understanding of course content, concepts, and material*
- *Study habits, time management skills, and note taking skills*
- *Problem-solving skills*
- *Critical thinking and analytical skills*
- *Ability to complete the course*

The response categories used were: (1) not at all, (ii) slightly, (iii) moderately, (iv) considerably, and (v) a great deal. Because the response distributions from both courses were very similar, Figure 3 shows the main results for only the Business Statistics course to avoid duplicity.

The overall conclusions from these analyses showed a positive perception about SI among all attendees for

Figure 3. Student Response Rates to SI Surveys for the Business Statistics Course

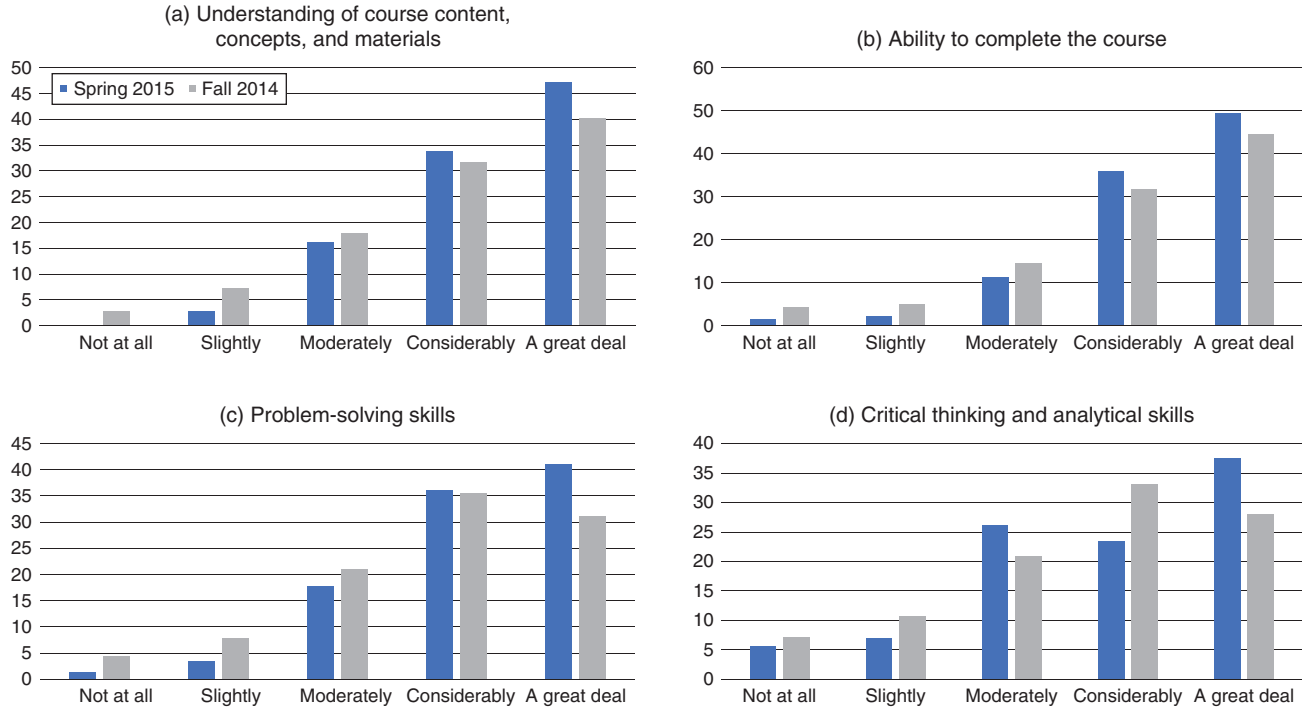


Table 10. Students' Overall Satisfaction with the SI Program

	Spring 2015 (%)	Fall 2014 (%)
Very satisfied (8–10)	85.9	72.9
Moderately satisfied (5–7)	11.3	21.4
Slightly or not satisfied (1–4)	2.8	5.7

both courses. For the Business Statistics and Management Science courses, 76% and 80% of the students, respectively, believed that SI significantly helped them improve their understanding of course content and materials; 72% and 74% believed that SI helped them improve their problem-solving skills to a great extent, and 75% and 76% mentioned that SI helped them to significantly improve critical thinking and analytical skills. Around 80% of students attending SI for both courses believed that SI helped them to a considerable extent in their ability to successfully complete the course. Their overall satisfaction with the SI program, as summarized in Table 10, clearly shows that a majority of students, over 90%, were highly or moderately satisfied with their SI experience. Furthermore, nearly 70% of the students mentioned that they are definitely likely to attend SI sessions in the future, and over 95% said that they would recommend SI to their friends and peers. Satisfaction with the SI program can also help students change their attitude toward bottleneck courses, which in turn increases their chances of passing such courses.

There were slight differences in response distributions for the two Semesters; this can be attributed to natural variations due to different SI leaders and the perception and type of students who attended the sessions. Moreover, in Fall 2014, the SI program was relatively new, and some minor issues (mainly technical) might have had an adverse impact on student opinions. These issues were resolved before Spring 2015.

7.1. SI Leader Perceptions

SI leaders form the nucleus of the SI program and are responsible for its success to a great extent. Yet SI leaders are also students, and for many of them this is the first opportunity to assume a leading facilitator role in the classroom. This means opportunities for personal, academic as well as professional development that are worth exploring apart from the impact of SI on student performance that forms the primary objective of this research.

Ten SI leaders from the two business courses (five from each) over the two semesters completed surveys at the end of each semester. All of them reported excellent overall experience with the program, with 90% believing that it contributed significantly to their academic and professional growth. Their responses to some questions, reported on a scale of 1–5 (lowest to highest), are summarized in Table 11. In their comments, they praised the program highly and expressed gratitude for the opportunity participate.

Table 11. SI Leaders' Response Summaries to Some Survey Questions

	Mean ($n = 10$)	Standard deviation
Organizational skills	3.60	1.17
Communication skills	4.30	0.82
Leadership skills	4.20	1.14
Ability to work with other of diverse backgrounds	4.00	1.05
Feeling valued in your department/ College	4.20	0.92
Belief about making a difference in others' lives	4.30	1.06

8. Conclusions

Many students struggle in quantitative business courses, which are often considered bottleneck courses. Such students require additional help and support to successfully complete these courses before they can go on to the next set of courses required for degree completion and timely graduation. SI is such a resource, targeted to all students with the goal of improving overall student learning and success in difficult courses. Although SI has been prevalent on our campus for a few years in other disciplines, its introduction in business courses is relatively new. Our results thus far have been positive; improvement in students' performance was noted across two core business courses over a period of one academic year. In particular, we identified subpopulations of students who benefitted most from attending SI sessions; our findings showed significantly higher improvement in the probabilities of passing for students who are identified as at risk based on background factors. The added benefit of consistently attending SI sessions (i.e., more than eight sessions during a semester) was also established. This implies that students who attend fewer sessions, possibly just before exams, are unlikely to show significant improvement in terms of course grades.

Our predictive models also successfully predicted the effectiveness of SI in improving the likelihood of students' passing these courses, as well as consistent SI participation, while controlling for demographic and academic factors. The latter is crucial as our previous results demonstrated that a key to success is attending a significant number of SI sessions. Based on models from one semester, we predicted consistent SI participation in a future semester with around 90% accuracy, as established via cross-validation results. These results facilitate planning course logistics and budget in terms of allocating resources, such as the number of

SI leaders to hire (and hence their salaries), the number of rooms to allot, etc.

Apart from our quantitative analyses, qualitative analyses showed positive perception of the SI experience for students and SI leaders. Students in both courses, in both semesters, strongly believed that SI helped improve not only their understanding of course content but also the problem-solving, critical thinking, and analytical skills that are key to success in quantitative courses. SI leaders stated that experience helped them to develop their leadership and communication skills and enhanced their ability to work with peers of diverse backgrounds. In summary, SI offered an enriching and fulfilling experience to all students who participated in the program, including SI leaders.

8.1. Discussion and Limitations

SI is growing as a resource to help improve students' academic success at educational institutions worldwide. The analyses and results presented here from two semesters in 2014 and 2015 are for traditional face-to-face courses; our sessions follow the standard SI model. Our research has focused not only on the amount of improvement achieved as a result of SI but also provided insights about which students benefit most from this program, and predicted which students are more likely to regularly attend these sessions. The latter aspects of our research are relatively novel and, to our knowledge, are not covered in the current SI literature, although studies on SI effectiveness are prevalent for all disciplines.

The advent of technology has also paved the way for different kinds of supplementary learning resources, including online videos and tutorials, lecture recordings, interactive quizzes, and adaptive learning solutions. All these provide students with additional support to help them succeed in different courses, face-to-face and online; this may be especially true for the more difficult courses for which students with many supporting materials may be less willing to regularly participate in SI, particularly if there are schedule conflicts and other commitments. Because this may also be a potential limitation that results in lower SI attendance, many colleges and universities are exploring ways to make SI sessions more attractive by creating flexible schedules (e.g., multiple sessions at different times) and introducing *Online SI*, which is conducted remotely and, typically, on weekends or late evenings to accommodate more students. Currently, we are exploring ways to incorporate technology-based tools and resources into our courses; we are also piloting online SI for course sections. One avenue for future research would be a comparison of outcomes from our current study with outcomes of future semesters after these changes have been implemented. Moreover, given that students now are accustomed to technology in all walks of life, efforts are needed to introduce innovative technology-driven elements, , such iPads and other interactive solutions, into SI sessions.

The success of SI depends to a large extent on SI leaders, who are recruited, trained, and led by an SI supervisor. SI leaders are not tutors or teaching assistants; their role is not to introduce new content or to reteach lecture material. The SI leader facilitates discussion around course content and related study skills. That said, however, students attending SI for the first time are at times frustrated when they do not receive the kind of one-on-one assignment help they have come to expect from tutoring. As such, instructors need to set clear expectations by explaining to students the exact purpose of SI. Similarly, instructor help is crucial for increasing overall student participation, and to encourage more students, particularly those at risk, to regularly attend SI sessions. This will further reduce attrition and failure rates for bottleneck courses.

Although this was a preliminary exploration of certain aspects of SI in the business discipline, it has opened numerous opportunities to extend our research. Our current and future work includes continuous assessment and improvement of these programs to offer an even better student experience, build more robust statistical models to investigate the relationship of SI with various background factors, and more accurately predict SI participation over longer time spans. We believe that our results provide valuable insights for educators at other institutions who may face similar challenges with bottleneck courses in the business discipline.

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