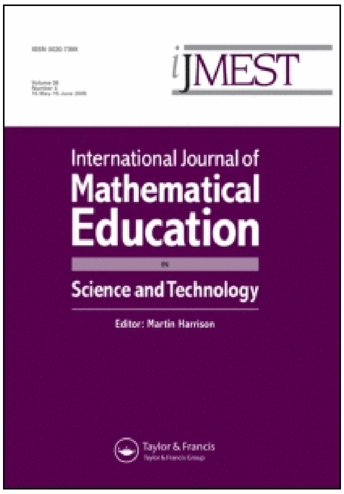

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# An evaluation of the Supplemental Instruction programme in a first year calculus course

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# An evaluation of the Supplemental Instruction programme in a first year calculus course

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Supplemental Instruction (SI) incorporates collaborative learning in small, peer-led, group settings in order to integrate instruction in learning and reasoning skills with course content. Several meta-analyses speak to the efficacy of SI but fail to address selection bias due to ability/motivation and gender. In this study, SI was paired with a first year calculus for non-majors course. An ANCOVA indicated that: ability/motivation, as measured by prior grade point average, was a useful predictor of course letter grade; gender differences were statistically significant but trivial; and, SI participation was statistically and practically significant, a 1.8 letter grade improvement after correction for selection bias. For the pass/fail analysis, a sequential binary logistic regression indicated there was a sizable statistically significant improvement with SI participation after accounting for gender and ability/motivation selection biases. The odds of success were 2.7 times greater for the SI participants. No gender differences of any significance were found.

**Keywords:** Supplemental Instruction; calculus; assessment; collaborative learning

## 1. Introduction

### 1.1. *Decision to implement Supplemental Instruction*

Growing demands for mathematics assistance at a small Canadian university resulted in a comprehensive inquiry into best practices for Mathematics support. Although several support mechanisms were in place (course specific tutorials, one-to-one tutoring and instructor office hours), there was a need for a new approach. Students were not attending regularly scheduled course tutorials, except perhaps just prior to an exam, at the time where a single tutorial was inadequate for most students. As for the one-to-one tutoring program, some students viewed this type of assistance as remedial and as a result, students who may have benefited from tutoring were reluctant to access the program. Instructor office hours were also not being used often as students frequently hesitate in seeking help from the instructor for fear of appearing inept. In efforts to address the situation, and after considerable collaboration with the Mathematics Programme, we piloted Supplemental Instruction (SI) in a calculus for non-majors class (MATH 152). SI was chosen for several reasons: non-remedial image; learning and study skills are situated in the context of the course being supported; student assistants are near peers; and most-importantly,

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the programme's guiding principles are solidly entrenched in contemporary theories for learning Mathematics as illustrated in the central themes that follow.

### 1.2. *The nature of SI*

Many academic support programmes have been developed to assist low-achieving students in first-year courses at the post-secondary level. In contrast, SI was developed to improve the learning of students in historically difficult courses. The SI programme evolved in response to the academic needs of students enrolled in problematic courses in professional programs such as the School of Medicine, Dentistry and Pharmacy at the University of Missouri-Kansas City (UMKC) [1]. It has since been used extensively in a wide range of graduate, undergraduate and professional school courses and in a wide range of disciplines [2–4]. The underpinning structure of the SI programme evolved as a result of collaborative learning theory and a need for improved practices that extend beyond generic study skills. Martin and Arendale [1] petitioned for a programme with reasoning and study skills integrated into the course content; not isolated from it. Consequently, the SI programme developed with the following principles.

(a) Service is attached directly to a specific course. Reading, studying and problem-solving skills are offered in the context of the targeted course. Instruction in these skills is developed out of student questions and concerns as they occur within the class and sessions.
(b) Service is proactive rather than reactive. The SI programme is implemented in the first 2 weeks of class to provide assistance before students earn a critical D or F grade on an assignment or examination. However, all students are encouraged to participate as much for the socio-cultural aspects as the academic support.
(c) Supplemental Instruction leaders attend all classes for the targeted course. Both the SI leader and the student are hearing the same lecture, creating an immediate point of reference for the students and SI leader. Furthermore, the SI leader is able to clarify what was said in the lecture, thus avoiding the common pitfall of student misconceptions about what occurred in the lecture. The SI leader, a student who has previously demonstrated superior academic achievement in the course, is provided with a timely review and often gains deeper insight into the course content upon hearing the concepts explained for a second time. The leader is also able to draw on his/her knowledge of the objectives of the course, thus creating an ideal learning environment for students attending the SI sessions as they strive for success.
(d) Supplemental Instruction is not remedial. The programme evolved as a means to improve student achievement in historically difficult courses. While some of the students attending the sessions may be underachievers or under-prepared, internal motivation is an integral component of students who participate in the SI programme [5].
(e) Supplemental Instruction programs are designed to provide a high-degree of student interaction and mutual support. SI has relied upon the power of group study for over 30 years and is built on the practice of collaborative learning and interaction through peer study groups facilitated by a near-peer.
(f) Supplemental Instruction leaders are trained. A key element of SI is extensive SI leader training particularly in group facilitation practices. For example, the SI leaders are trained to use proactive and participative activities in the sessions

such as 'think, pair, share' where students are encouraged to brainstorm ideas, pair up with another student and discuss their views or approaches to problem solving. The leaders are trained in questioning techniques based on Bloom's taxonomy [6]. Bloom's taxonomy is comprised of six levels: knowledge (primarily recall of information such as formulas), comprehension (articulates and understands the meaning), application (generally performing operations in mathematics), analysis (problem solving), synthesis (combining concepts for a deeper understanding) and evaluation (making judgments on the basis of the given data). SI leaders also assess skills through the development of quizzes that incorporate Bloom's taxonomy. These quizzes are not for marks, but are often open book, and are generally completed in collaboration with other students. Quizzes provide students an opportunity to practice for tests, thus reducing the test anxiety that often accompanies mathematics tests and helps to build confidence. The SI leader draws on his/her previous knowledge of course goals and what is currently being discussed in lecture to prepare practice questions and tests. SI leaders implement strategies in sessions such as generating a table of contents, built on student input. These tables assist students in summarizing the key concepts taught in a chapter or a unit, perhaps to be tested in an upcoming exam. Another strategy is to have students generate potential test questions; compile a quiz based on these questions; administer the quiz and then discuss solutions.

(g) Supplemental Instruction is supervised. Even with an initial 8 hour training session in group facilitation methods and instruction in SI philosophy and guidelines, leaders can slip back into the familiar tutorial structure in which they answer student's questions at the board. Ongoing training and monitoring for approved SI practices is essential. Our university Math/Stats Advisor (the first author) underwent a prescribed three-day training programme at UMKC to ensure that correct practices were undertaken when establishing, supervising and monitoring the SI programme at this university.

The guiding practices of SI reflect current ideology for learning by creating opportunity for discourse in the language of the discipline [7–12]. Furthermore, SI philosophy is congruent with two major learning theories, both of which are examined in the following discussion.

## 2. A theoretical framework for SI

Two major hypotheses evolved during the course of the last century that have influenced current conceptions of acquisition of knowledge. The first of these, Piaget's theory of 'constructivism', challenged the idea that knowledge is passively acquired. The second theory, sometimes referred to as 'social constructivism' is a Vygotskyian philosophy that argues learning occurs through social interaction in meaningful contexts. Vygotskyian theory emphasized the importance of culture and social interaction in accounting for individual development. Consequently, educators need to create learning environments where communication, conversation and scaffolding are provided to assist students to construct the knowledge they need to acquire. Mathematics conversation can lead to a deeper understanding of the language of mathematics. Through communication, ideas are reflected upon, refined and remembered. As students learn to speak mathematical language, they transform their thinking of the mathematical concepts. The creation of mathematical knowledge is thus improved by making meaning through processes of social interaction and language [13–20].

Gee [8] stated that enculturation is best accomplished through scaffolded and supported interactions with people who have already mastered the discourse (not necessarily by a teacher) – exactly the type of environment strived for within the SI sessions. The SI leader is the teacher/facilitator who has previously mastered the course being supported and who actively engages students in interactive learning situations. SI leaders provide scaffolding as students learn to think within the context of the course. They provide directions, suggestions, and clarify concepts and theories, thus reflecting the meaning-making intended by Gee and other theorists. Linn and Kessel [10] assert that scaffolding is most effective if it involves tasks within the learner's zone of proximal growth, another Vygotskyian concept. The zone of proximal growth is the state of the individual's current potential for further intellectual development. Vygotsky believed that through the use of scaffolding, the individual may rise to further understanding and the scaffolding can be achieved through modelling, feedback and dialogue [21]. Through extensive training, the SI leaders develop the skills necessary to model effective learning and study strategies in the discipline, to provide constructive feedback to students, to support student interactions in the SI sessions and practices that reflect modern pedagogy for learning mathematics.

Current research also suggest that students should to be given an opportunity to develop personal initiative and responsibility, to acquire adaptable problem-posing and -solving skills, and to increase their ability to work collaboratively with others [22,23]. The voluntary nature of SI provides students with the opportunity to take responsibility for their learning, and with the aid of an SI leader, to develop problem-solving skills all within a collaborative setting. Students are encouraged to discuss course content, analyse and refine ideas, and become conversant with the topics at hand. Thus, the SI leader, through facilitation, interaction, scaffolding and explanation promotes learning in a socially non-threatening environment where students can 'safely' make mistakes and open discussion is a means for clarifying concepts; a learning situation similar to what Vygotsky, and recent theorists such as Wells [12] and Gee envisioned. The underpinning philosophy of SI is congruent to models proposed by both Piaget and Vygotsky, and confirms that the SI programme strategies are established on a solid theoretical foundation.

## 3. Efficacy of SI

Studies have shown that SI has improved student achievement, most notably in the decrease of D and F letter grades and increased grade point average (GPA) among students who attend SI [24–27]. Twice, the US Department of Education validated the SI Programme as an *Exemplary Educational Program*. The SI Programme is one of the only two programs that are officially recognized by the US Department of Education as contributing to increasing student graduation rates.

Several studies on SI are compilations of research over thousands of students and across decades. Three such studies are described in more detail. The Centre [sic] for SI has been monitoring the effectiveness of SI since its inception in 1973. The Centre compiles and analyses data submitted by over 100 college and university SI programmes annually using a quasi-experimental design and longitudinal analysis of SI effectiveness. In their analyses, a student was categorized as a participant if he/she attended at least one SI session. Chi-square analyses and *t*-tests were used to determine SI significance for improving course grades, decreasing D, F and W (withdrawal) grades, and improving retention trends. It should be noted that in the North American context, a D grade gives a student credit for a course but often disqualifies a student from using the course as a prerequisite for subsequent coursework. Hence, we grouped a D grade with the failing grades in our study. The first UMKC analysis included data collected over a 19 year period, in 525 courses, for a total of 19,962 SI participants and 31,368 non-participants. Chi-square analyses revealed significant differences with a reported 54% of SI participants earning A and B grades in comparison to 43% of non-participants. Similarly, the Centre reported significant decreases in D, F and W grades amongst SI participants (20% *vs*. 34%).The Centre also calculated an overall significantly improved mean GPA value (2.7 *vs*. 2.4) using the following scale for grades: $A=4$, $B=3$, $C=2$, $D=1$, $F=0$. These results were replicated using the criteria of attendance at five or more sessions; once again there was a statistically significant improvement favouring SI participants.

Similar results were reported by the Centre for SI on data collected from other institutions. The national data were provided by 270 institutions between 1982 and 1996, composed of 4945 courses offering SI to over 500,000 students. In the first analysis, the courses were categorized as Business, Health Science, Humanities, Mathematics, Natural Science and Social Science. The Centre reported higher mean course grades across all disciplines, a notably higher percentage of A and B grades, and a lower percentage of D, F and W course grades. There were 815 courses in the Mathematics category with considerable increases in A and B grades and decreases in D, F and W grades but oddly, a non-significant improvement in mean course grades (2.2 *vs*. 2.1). A third study of American national data, based on 143 Calculus courses supported by SI, again revealed notable increases in A and B grades and decreases in D, F and W grades, with a subsequent improved mean grade (2.3 *vs*. 2.1). Similar results were reported for college algebra, finite mathematics and statistics courses indicating SI is effective in a range of Mathematics courses offered at a variety of institutions across the US.

A more recent study undertaken by Burmeister, Kenney and Nice [25] demonstrated that SI participants earned significantly improved grades in college algebra, calculus and statistics courses. Their research contained data obtained from 45 different institutions in 177 mathematics courses for a total of 11,252 students. They reported that SI participants earned higher mean final course grades in algebra, calculus and statistics, and experienced lower rates of withdrawals. Burmeister et al. reported that 32% of students attended SI sessions with participation at sessions ranging from 5% to 88%. Surprisingly, their study revealed that SI participants earned more D grades than expected but the rate of withdrawal from their respective courses was lower than their non-participant counterparts. Burmeister et al. raise questions in relation to their research, specifically: How closely did each of the institutions follow the SI model; and were the groups of SI participants similar from campus to campus?

These unanswered questions indicate a need for further analysis of the SI program. Furthermore, in spite of several large meta-analyses, a number of methodological problems remain. First, there was an inability to document the degree of SI treatment throughout the sampling. Second, there was no consistent attempt to address the likely selection bias that would result from students making the choice to attend SI sessions or not. Third, student's ability was not considered nor was gender examined in any detail, despite increased female enrolment in mathematics. There has been considerable research examining performance differences with older studies reporting results favouring males.

Also, there may be differing SI participation rates between genders. We conducted our research with these questions in mind.

## 4. Analysis of SI after adjustment for effects of gender and ability/motivation

### 4.1. *Research questions*

Two related questions form the basis for our study. First, is SI seen to improve the course grades of students enrolled in calculus for non-majors once there has been statistical adjustment for the effects of gender and ability/motivation? Second, is SI seen to improve the success rates of students enrolled in calculus for non-majors once there has been statistical adjustment for the effects of gender and ability/motivation?

### 4.2. *Method*

As students could not be randomly assigned to SI and non-SI groups, we regard this study as a quasi-experimental design. It is not a non-experimental, *ex post facto* design as V. Fayowski was primarily responsible for administration of the treatment (the SI programme). However, this quasi-experimental design raises the possibility of selection bias. Two opposing issues arise, the first is that a higher proportion of weaker or less motivated students join the SI programme, and the second is that more highly motivated students join the programme, both in order to achieve higher grades in mathematics. We have chosen to statistically adjust for these possible differences through the use of a covariate consisting of the students' prior grade point average.

The SI supervisor (V. Fayowski), who was trained in SI practices at UMKC, ensured SI procedures were followed throughout the duration of the research. Instructor support, an integral component of successful SI, was obtained for all MATH 152 classes prior to implementation of the programme. Student leaders were recruited and trained in order to introduce SI in the first 2 weeks of classes, in courses that are typically 13 weeks long, in efforts to provide immediate and proactive support. Three 50 min sessions per week per leader were scheduled in such a way as to provide maximum accessibility for all students enrolled although there were some occurrences of scheduling conflicts. We were able to limit these to less than three to four students per class throughout the duration of the research. Student attendance was monitored by the SI leaders.

All students were informed of the support available through the SI programme and of other mathematics assistance available to them at the university: one-to-one tutoring, instructor office hours and traditional tutorials. After three semesters, it became apparent that students were not attending the traditional tutorials even though excellent mathematics students were placed as tutorial assistants for MATH 152. This had been the case prior to SI availability and was one of the main reasons for seeking out a new support system. Students were attending the SI sessions, thus a primary purpose of the programme was realized.

### 4.3. *Measures and procedures*

Final grades and SI attendance were collected from Winter 2002 to Fall 2004 resulting in data for 869 students enrolled in nine sections of MATH 152. Of these, 269 students were classified as SI participants forming the first group; the remaining 600 non-participants formed a second group. Data was obtained for a further 390 students enrolled in

Table 1. Final MATH 152 grades numerical conversion.

| LG | SCALE | LG | SCALE | LG | SCALE | LG | SCALE |
|---|---|---|---|---|---|---|---|
| A+ | 12 | B+ | 9 | C+ | 6 | D | 3 |
| A | 11 | B | 8 | C | 5 | F | 2 |
| A− | 10 | B− | 7 | C− | 4 | W | 1 |

MATH 152 from the year prior to SI implementation, forming a third (pre-treatment) group. For the purpose of analysis, the letter grades, the dependent variable, were converted to numerical values (Table 1) and used to compile the statistics that follow. Note that we decided to give a Withdraw (W) a lower score than a Fail (F) as we believe that the common case of student withdrawal from a course was an early self-assessment as to the probable lack of positive outcome. In the case of an F, the student had at least remained in the course long enough to be given an F. The student likely wrote the final examination with the expectation of passing. Hence, an F was given a scale point of 2.

The covariate, prior GPA, was created from the students' available records. In the majority of cases, students enrolling in MATH 152 had a prior GPA based on coursework undertaken at our institution. In the case of transfer students without coursework, then their transfer GPAs were used. Transfer students automatically have their grades converted to the same metric as used at our institution, resulting in a comparable value. If a student had neither an institutional GPA nor a transfer GPA then the Grade 12 average percent was converted for use in the analysis. Gender information was available as part of the university student records.

After examining the frequency of attendance data, we decided that attendance of less than five of the available SI sessions would be considered non-attendance. This cut point fit well with natural breaks in the data and with our belief that a student could not possibly be expected to display benefits of SI with lower numbers of sessions. This put us at variance with some earlier researchers who categorized attendance at one or more sessions as SI participation. We classified students who took MATH 152 prior to the implementation of SI as a Pre-SI group in a first attempt to assess the effects of possible selection bias and as an indicator of whether or not any grade inflation or other changes in grading practices had taken place in the pre-SI to SI time period.

## 5. Results

### 5.1. *Analysis prior to correction for selection bias*

Analysis prior to correction for selection bias and gender was limited to a comparison of the letter grade distributions and success/failure rates for each of the groups. Pre-SI students received a mean grade of 4.9, almost a C; non-participants received a mean grade of 5.4, or a mid-C; and SI participants earned a mean grade of 6.9, almost a B−. The lower mean of the pre-SI group (a mixture of non-SI and potential SI individuals had there been the opportunity to participate) suggested the possibility of changing standards or of grade inflation. A one factor ANOVA test confirmed evidence of statistically different grades ($F = 26.8$, $p < 0.0005$). Tukey *post hoc* testing revealed that the only differences were between the SI group and the other two groups. The SI participants out-performed the non-participant and pre-treatment groups; furthermore, these latter groups did not differ from one another.

These data were re-examined using a two-way contingency table to analyse proportions of success to failure in the three groups. All A+ to C− grades were included in the success group; the D, F and W grades were placed in the failure category. The pre-SI group had a success to failure rate of 47–53%; non-participants 53–47%; SI participants 73–27%. The Pearson Chi-square test (($\chi^2_2 = 43.4$, $p < 0.0005$)) confirmed that statistically significant differences existed. However, these results are merely suggestive of the efficacy of SI as the issue of bias due to self selection has not been accounted for in these data, nor have issues of gender been resolved. There may be differences in achievement. This is further complicated in that one gender may be more disposed to seek out additional mathematics help. Therefore, gender has been included as a variable in all further analyses. Based on our preliminary analyses, there was no evidence to support differentiating the pre-treatment and non-participants, and consequently these two groups were amalgamated under the name of 'non-participants'.

### 5.2. *SI effects corrected for prior academic achievement and gender*

The next two analyses, an analysis of covariance (ANCOVA) and a binary logistic regression, included the ability/motivation covariate (prior GPA) and gender. Gender differences in mathematics performance have been of interest for decades, with current research now suggesting little or no difference in performance [28–30]. The inclusion of gender allowed us to determine whether SI has differing degrees of efficacy for male or female students. Furthermore, the inclusion of gender as a variable creates a more sensitive statistical analysis, that is, effects have less chance of being overlooked in the analyses. The first analysis, ANCOVA, was appropriate for the investigation of change in final letter grade due to the implementation of SI. Binary logistic regression was chosen for the success/failure analysis.

### 5.3. *Correction of achievement (letter grades) results using prior GPA*

An ANCOVA was performed to assess the difference in final grades between SI participants and non-participants after adjusting for ability and inclusion of gender as a factor. Adjusted mean grades and standard deviation statistics are presented in Table 2 while the summary ANCOVA results are presented in Table 3. The ANCOVA results are interpreted as follows. The prior GPA is a statistically significant predictor of success in MATH 152. This was expected; it would not have been included in the analysis had it not been true. The SI/gender interaction is non-significant, that is, there is no differing effect of the treatment for males and females. This result is desirable; one would not want a programme that was effective for one gender and not for the other. In contrast, gender was statistically significant but a Cohen's $d$ value of 0.2 represents a marginal effect size, less than one letter grade difference between males and females. Of greater interest, there were significant differences in performance even after correcting for prior GPA and gender! Participation in SI improved grades even after accounting for ability/motivation, and gender. Furthermore, SI treatment was of practical significance as well. The Cohen's $d$-value of 0.5, a medium size treatment effect, signified an overall 1.8 letter grade difference favouring SI participants!

Table 2. Mean final grades (by gender and SI treatment).

| SI 2 category | Gender | Number | Mean grade (adjusted) | SD |
|---|---|---|---|---|
| Non-participants | M | 509 | 4.8 (C−) | 3.4 |
| | F | 481 | 5.6 (C) | 3.7 |
| | Overall | 990 | 5.2 (C) | 3.6 |
| SI participants | M | 135 | 6.6 (C+) | 3.5 |
| | F | 134 | 7.2 (B−) | 3.6 |
| | Overall | 269 | 6.9 (C+/B−) | 3.6 |

Table 3. Summary of ANCOVA results.

| Source | MS | *F* | *p* |
|---|---|---|---|
| Prior GPA | 3186.8 | 316.9 | 0.000 |
| SI treatment | 520.1 | 51.7 | 0.000 |
| Gender | 74.9 | 7.5 | 0.006 |
| SI * Gender interaction | 10.1 | 1.0 | 0.316 |
| Residual | 10.1 | | |

### 5.4. *Correction of success (pass/fail) rates for prior GPA*

This test was performed to determine if SI participation contributed significantly to prediction of success or failure after accounting for the effects of prior GPA and gender. The results are displayed in Table 4. The first mathematical model (Model 1) tests whether prior GPA and gender statistically predict outcomes of success or failure are better than no model at all. We accept the idea that prior GPA and gender are predictors of success/failure in MATH 152 for the population of students who take this course given the observed values $\chi^2_2 = 182.9$, $p < 0.0005$. The SI treatment was then added to the model (Model 2) and as we might expect these three predictors as a group are successful at predicting success. Note that the chi-square value increases with the added predictor. Of most interest in this study is the difference in chi-square values between the two models. With an observed difference of $\chi^2_1 = 41.2$, $p < 0.0005$, we have evidence that SI participation is a significant contributor to prediction of success in MATH 152, after accounting for both gender differences and prior GPA. The effects of each of the three predictors were examined in more detail. These results are presented in Table 5. The Wald test was used to determine the statistical significance of each of the predictors, SI participation, prior GPA and gender, in this model. As was already determined, SI treatment was a significant predictor of success as was prior GPA. However, gender was not significant when the effects of prior GPA were taken into account. Prior GPA, an achievement measure, is not only a measure of ability, but is also influenced by motivation and was a good choice for a covariate. This sequential model demonstrated that SI participation had an effect on success in MATH 152, calculus for non-majors, after the issues of possible selection bias were accounted for. As with the ANCOVA, there is a measure of the importance or practicality of these predictors. The quantity $e^B$, in Table 5, represents the ratio change in the odds of success for a one-unit change in predictor. For example, the odds of a person succeeding are 2.7 times greater as a result of SI participation while one unit of prior GPA (note, on our

Table 4. Sequential logistic regression results.

| Model | $\chi^2$ | d*f* | *p* | −2 log likelihood |
|---|---|---|---|---|
| Model 2 GPA, gender, SI | 224.1 | 3 | 0.000 | 1506.7 |
| Model 1 GPA, gender | 182.9 | 2 | 0.000 | 1547.9 |
| Effect of SI | 41.2 | 1 | 0.000 | |

Table 5. Variables in the prediction model.

| Variable | B | SE | Wald | d*f* | *p* | $e^B$ |
|---|---|---|---|---|---|---|
| SI | 0.992 | 0.160 | 38.333 | 1 | 0.000 | 2.696 |
| GPA | 1.103 | 0.092 | 144.089 | 1 | 0.000 | 3.014 |
| Gender | 0.146 | 0.125 | 1.365 | 1 | 0.243 | 1.157 |
| Constant | −4.157 | 0.364 | 130.205 | 1 | 0.000 | 0.016 |

university's scale, 3 letter grades) had only a slightly greater effect. Gender, if it were statistically significant, would be of no predictive value as the odds ratio is ~1. The mathematical model accurately predicts student outcomes 68% of the time.

## 6. Discussion

### 6.1. *Conclusions*

Supplemental Instruction can be credited with a two-letter grade increase for students participating in the programme after controlling for selection bias and gender differences. This is a substantial increase in outcome, in particular, since the average grade of non-participants was a C and the average grade of SI participants was a B−. Male and female students benefited equally from SI participation. When we focused our concern on successful completion of MATH 152, we found, even after controlling for prior GPA and gender, success rates for SI participants were considerably higher than for non-participants. The advantage of SI participation on the success/fail rate is roughly equal to an increase of three university letter grades of prior GPA.

Comparison between our study, with its 12-point letter grade scale for class outcomes and the 4-point scale described in Section 3, should be made with caution. Nevertheless, when our results are converted to the 4-point scale, they exceed any of the published results by three times that of the median result reported. Our study properly corrected for gender and ability/motivation biases and yet still supported the work of other researchers who may not have consistently controlled for these effects [2,9,24,25].

Furthermore, we have drawn attention to the underpinning theories that provide explanation for the efficacy of the SI programme. This programme acts to provide students a socially meaningful context to acquire the knowledge needed to succeed in the course. By attending SI sessions, students are being supported using innovative techniques that emphasize process-related learning through scaffolding, dialogue and breaking down of material into parts to promote learning in a socio-cultural context, similar to what Vygotsky and recent theorists such as Wells and Gee envisioned.

### 6.2. *Limitations*

Attending SI required a commitment by the student, and thus a self-selection effect can occur. It was critical to control this effect. By using prior GPA as a covariate, a measure which we believed to be a combination of ability and motivation, we attempted to minimize self-selection bias. However, circumstances change and so prior GPA may not have always reflected the current state of individual motivation. In addition, the prior GPA value was based on an amalgamation of transfer and high school grades, as well as institution grades, and may not have been as accurate a measure of motivation/ability as intended. It is possible that an under-adjustment of scores may have occurred.

We also cannot definitively state what aspect of SI contributed to the improved grades. Might an equal amount of group study time achieved similar results to those observed in the research? We reported treatment effects as three times the size of the other studies. We can only speculate as to whether this may be due to better control over the SI process, the greater sophistication of our design (statistical control of gender and achievement/motivation), or an increased sensitivity due to our 12-point grade system.

### 6.3. *Questions for practise or research*

One consideration which is not addressed in our research is that of ethnicity. For example, some cultures discourage student questioning and it may be seen as disrespectful to the instructor and/or the SI leader if a student asks questions. Other remaining questions include: What effect does serving as an SI leader have on the SI leader? Do students who participate in SI improve their study habits? If so, do the study habits transfer into other classes? Do SI groups become learning communities that continue outside the SI supported course? Further research into these questions and other issues that arise is warranted in order to fully understand how students best learn mathematics.

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