Engineering Supplemental Instruction: Impact on Sophomore Level Engineering Courses

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Dr. Wang's research interests focus on the development of feasible solutions to practical radiation protection and radiation detection issues. The majority of his work has emphasized operational radiation safety, radiation detection instrumentation, air monitoring methodology, and radioactive waste management. He has authored or co-authored more than 30 peer-reviewed publications, conference proceedings and abstracts, and book chapters. He has also chaired five graduate committees and served on another 16 graduate committees. In addition, he has served as a manuscript reviewer for four referred journals (i.e., Environmental Health Insight, Health Physics, Medical Physics, and Nuclear Instruments and Methods in Physics Research Section A).

Dr. Wang received Commendation for Excellence in Teaching five times at LSU. He was the Herman Cember Memorial Lecturer at the 2013 American Industrial Hygiene Conference and Exhibition in Montreal, Canada. He also holds a U.S. patent on a real-time video radiation exposure monitoring system.

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Active learning strategies, through newly focused engineering Supplemental Instruction (SI) sessions, were provided in sophomore level, gateway engineering courses at Louisiana State University beginning in the spring semester of 2013. This program operates as an independent subgroup of the university's current SI program to allow particular focus on training engineering student leaders with effective teaching skills specific to their discipline. The goal of this effort is to improve student comprehension and passing rates in historically difficult gateway classes to engineering where most students fail or drop the course (earning D, F, or W). These courses include statics, dynamics, fluids, strengths, thermodynamics, and circuits. SI leaders providing the supplemental instruction sessions are required to attend the course lectures, to meet on a regular basis with the SI Coordinator and the course professor, to provide office hours for students, and to hold weekly sessions to review course material using active learning strategies. Implementing unbiased evaluation of the direct success of the program is difficult due to different instructors (each with different exams), different students, and other human factors; however, a few trends can be observed. Reported herein are preliminary results of the program across four semesters (two spring, one summer, and one fall). On average for all courses included in this program, students who did not attend any SI sessions were 60.62 ± 0.04 % likely to pass with an A, B, or C. Those who attended only a few sessions (one to three) had a 66.92 ± 0.07 % likelihood of passing the class. Students with regular session attendance (four or more sessions) had a fairly substantial increased likelihood of passing the course, 77.41 ± 0.09 %. This difference is statistically significant with a p value of less than 0.0001. Feedback from SI leaders show that the benefits of this program extend beyond the impact on those enrolled in the courses—SI's report an increase in their own understanding of the material covered in these courses, greater confidence in their ability to lead discussions, as well as other positive professional and personal growth.

1 Background

Increases in student enrollment, decreases in state higher education funding, and larger class sizes all contribute to a less conducive learning environment for students [1, 2]; all are a reality at Louisiana State University (LSU). Added to these difficulties, students are further challenged in their sophomore year of college as they struggle to convert study skills that in high school depended on bulk memorization to new more intense requirements of application-based processes. Students who did well freshman year sometimes do not pass major key courses in sophomore year [3]. Sophomore year is also the time where the majority of transfer students enter the College of Engineering. With this mix of challenges, many students end up dropping out of this academic and career choice [4].

Several active learning based programs attempt to alleviate these student difficulties and attrition by offering peer administered active learning sessions that help guide younger students to learn and to use skills necessary for success in STEM disciplines: Peer Led Team Learning [5, 6], Supplemental Instruction [8], and Learning Assistant recitation [7], etc.). Louisiana State University's College of Engineering determined that its students needed additional support in the traditional gateway courses of statics, dynamics, thermodynamics and circuits–courses that are

typically taken during a student's sophomore year. A model based off of Peer Led Team Learning [5, 6] and Supplemental Instruction [8] was chosen for these courses at LSU and Baton Rouge Community College (BRCC) through the NSF STEM Talent Expansion Program grant #1161311. The core goal of this grant is to increase the number of students graduating from the College of Engineering.

LSU's academic support department (the Center for Academic Success) and College of Engineering experimented with their current active learning session's organization by growing one of the models within engineering during the 2012-2014 academic years. This variation of the current approach would focus the existing university-wide program by specifically providing help for students taking historically difficult sophomore level engineering courses. The university's established Supplemental Instruction program was used and modified to better suit the needs of engineering students taking these courses. The changes included appointing a designated coordinator for the engineering student instructors, alternative training styles, and studies of other similar programs. These trained supplemental instructors employed active learning strategies through outside of lecture peer facilitated sessions (sessions) and peer facilitated office hours to engineering students enrolled in the selected courses. The goal of sessions and office hours was to improve student comprehension and retention rates in high DFW (percentage of students that withdraw, earn a D, or earn an F) engineering classes. This paper is a preliminary analysis of the implementation of this new SI model.

Supplemental Instructors (SIs) are undergraduate students in the College of Engineering who have taken and performed well in the course they wish to SI. They were initially required to have a verbal or written recommendation from the professor and to have above a 2.5 GPA. As the program grew, however, these requirements changed slightly, allowing for exceptions to these rules. For example, the student who served as SI in the circuits course for non-electrical engineers was an electrical engineering student who had taken the course for EE majors. He had a good relationship both instructors and knew the material very well, so we made the exception. We also added the requirement that SI Leaders need to be active members of the Society of Peer Mentors, a student organization that focuses on mentoring and leadership; this organization also serves as a pool for recruiting new SIs.

Each week SIs were expected to attend the lecture for their designated course(s), to lead two active learning sessions (90 minutes each), to hold office hours, to meet with the course professor, and to attend the weekly SI training meeting. Once a semester, the SIs also attended a half-day training workshop and were required to observe and report on at least one fellow SI's session. Once a year, SIs were invited to a faculty development workshop where active learning methods were discussed in much greater detail with engineering faculty. New SIs were paired with experienced ones to observe and to learn how to be an effective SI. Regular observations by and discussions with the coordinator allowed for consistent feedback.

The material covered during the weekly sessions was left up to the discretion of the SI, but it usually included some time spent recalling information discussed in lecture followed by a series of problems worked in groups and discussed. Strategies used by the SIs (learned from weekly training) include think pair share [9], group work, minute papers, scribe and orator [10], and simple techniques such as handing the white board marker to a student; these methods were recorded

through direct observations of SI sessions by the coordinator and other SIs. Overall, setting the goal to make SI sessions more interactive with less lecturing has been met by most SIs in most cases.

During weekly meetings, SIs also discussed academic papers regarding active learning, pedagogy, and conflicting teaching models with the coordinator. SIs were given access to the papers, but they were not required to read them (examples used in previous semesters [11, 12, 13, 14, & 15]). The paper would be introduced, major data displayed, and a discussion would take place about methods and involvement in their class. SIs were expected to make arguments as to why different methods would or would not work in their classroom, and they were periodically expected to adapt their current material to incorporate new strategies. Other topics of discussion include university policies and other resources that are often not known by the students (such as tutorial centers, academic counseling, and online resources).

Once a week SIs were expected to make contact with the course professor. This was not a requirement nor a minimum, as some professors did not have time to participate actively with the program. However, many professors regularly discussed material and strategies with their SIs. Some even requested to participate in the sessions (contradictory to the original idea of the peer instructed sessions). If students did not meet regularly with the professor, course attendance was a requirement. However, if a student had experience in the course, and met with the professor regularly exceptions were made if they had course scheduling conflicts.

The purpose of this paper is to ascertain the effectiveness of the Supplemental Instruction Program at LSU. While there are many ways in which to determine and define program effectiveness, we decided to measure success based on the passing rates earned by students in courses where SI is offered. Program effectiveness was also measured qualitatively through student, professor, and Supplemental Instructor evaluations and focus groups.

2 Methods

2.1 Context

The new SI program officially began in the spring semester of 2013 and has been slowly expanding ever since (Table 1). SIs regularly suggested there were major differences in student involvement and attendance during regular sessions compared to those sessions held before an exam; these differences in session attendance potentially take away from their ability to successfully provide an active learning environment. For example, some students have been reported to attend only sessions right before an exam to obtain the review handout. Course grades were analyzed separately for each course, each semester.

Rubric	Course Name	Semesters SI Offered
CE 2200	Fluid Mechanics (CE)	Summer 2013
CE 2450	Statics (all engineering)	Spring, Summer, Fall 2013 & Spring 2014,
CE 2460	Dynamics and Vibrations (CE)	Spring, Fall 2013, Spring 2014
CE 3400	Mechanics of Materials (all)	Spring 2014
EE 2120	Circuits (EE)	Spring, Fall 2013, Spring 2014
EE 2950	Circuits (Non EE)	Spring, Summer, Fall 2013, Spring 2014
ME 2334	Thermodynamics (ME)	Spring, Fall 2013, Spring 2014
ME 3333	Thermodynamics (Non-ME)	Fall 2013, Spring 2014
ME 3834	Fluid Mechanics (ME)	Spring 2014

Table 1. Engineering courses with SI offered at LSU, 2013-2014.
(CE Civil Engineering, EE Electrical & Computer Engineers, ME Mechanical Engineering)

2.2 Data Collection and Analysis

To evaluate the impact on students' passing rates in these courses, individual data was collected each semester from the university registrar. To date, attendance and grade data has been analyzed for 4 semesters. Students' session attendance was recorded by the use of sign-in sheets that were transcribed into spreadsheets at the end of the semester.

Attendance was analyzed for its relationship to student's earned letter grade and passing rate for the course. These data were split into three groups: students with no recorded attendance in SI sessions, students who attended a few sessions (1-3), and students who attended more than three SI sessions. Low attendance (1-3 sessions) and regular attendance (4 or more sessions) were grouped in this way based on SI leader feedback. The data were normalized by subtracting the passing rates of each SI attendance subgroup to the overall class average. In addition, all courses for all semesters examined were combined to ascertain at the overall trend in effectiveness of the SI program.

In addition to the course passing rates, student feedback about the SI program was obtained through surveys and focus groups. The surveys consisted of optional evaluation forms that were distributed to students by the supplemental instructors of each course. Completed evaluations were submitted to the coordinator by email or in person. Also, an outside evaluator held multiple focus groups for students who had taken engineering courses where supplemental instruction was offered as well as for the SIs themselves. The GPA of each SI Leader was also examined to see if they showed any improvement in their own grades after serving as SIs. The outside evaluator also conducted a focus group for faculty members who have taught courses with an SI.

3 Results

3.1 Impact of SI on passing rates of students

First, student grades were analyzed for each course separately (Figure 1). In order to examine the overall impact of the Supplemental Instruction Program, we wanted to look at trends both within and between courses. For each course, the difference was computed between the passing rate of each session attendance subgroup and the overall course average. For example, 65% of students

passed thermodynamics in Fall 2013, and only 32% of students who did not attend any SI sessions passed the course (Table 2). Therefore, the normalized passing rate for that subgroup is -33%, meaning that students who did not attend any SI sessions were much less likely to pass that class. Conversely, 79% of students taking this course passed with an A, B, or C when they attended 4 or more SI sessions. As seen in Figure 1, this class had the most dramatic difference in passing rates between students who attended SI sessions compared to those who didn't.

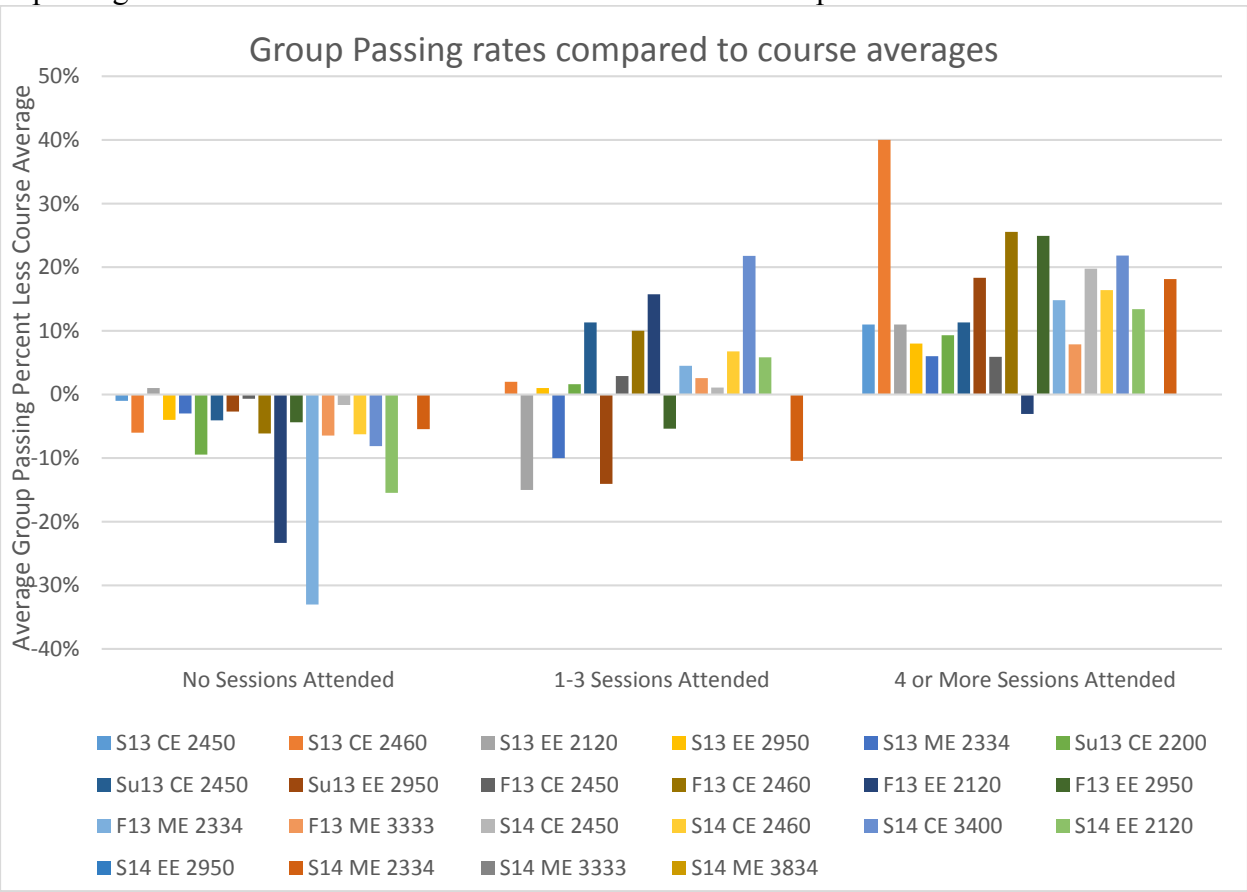

Figure 1. Passing rates normalized by course average for classes where SI was offered.

Fall 2013 ME 2334	Number of students with 0 sessions attended	Passing rate of students with 0 sessions attended	Number of students attending 1-3 sessions	Passing rate of students attending 1-3 sessions	Number of students attending 4 or more sessions	Passing rate of students attending 4 or more sessions	Total course enrollment	Total course passing rate
	38	32%	55	69%	68	79%	161	65%
Passing rates difference from Total Course Passing Rate		**-33%**		**4%**		**15%**		0%

Table 2. Example calculation for how passing rates were normalized between classes.

As seen in Figure 1, nearly all courses in all semesters examined show a similar trend. Students who do not attend any SI sessions obtain a D, F, or W at a higher rate than students who attend many SI sessions; results are quite variable for students who attend only a few sessions. When averaged across all courses, however, these data reveal that students who regularly attended sessions were 15±2% more likely to pass the course than an average student, and 22±3% more likely to pass than students who do not attend any sessions (Figure 2). It was also evident that students who attend only 1-3 sessions do not receive any statistical benefit compared to the average student performing 2±2% when compared to the average.

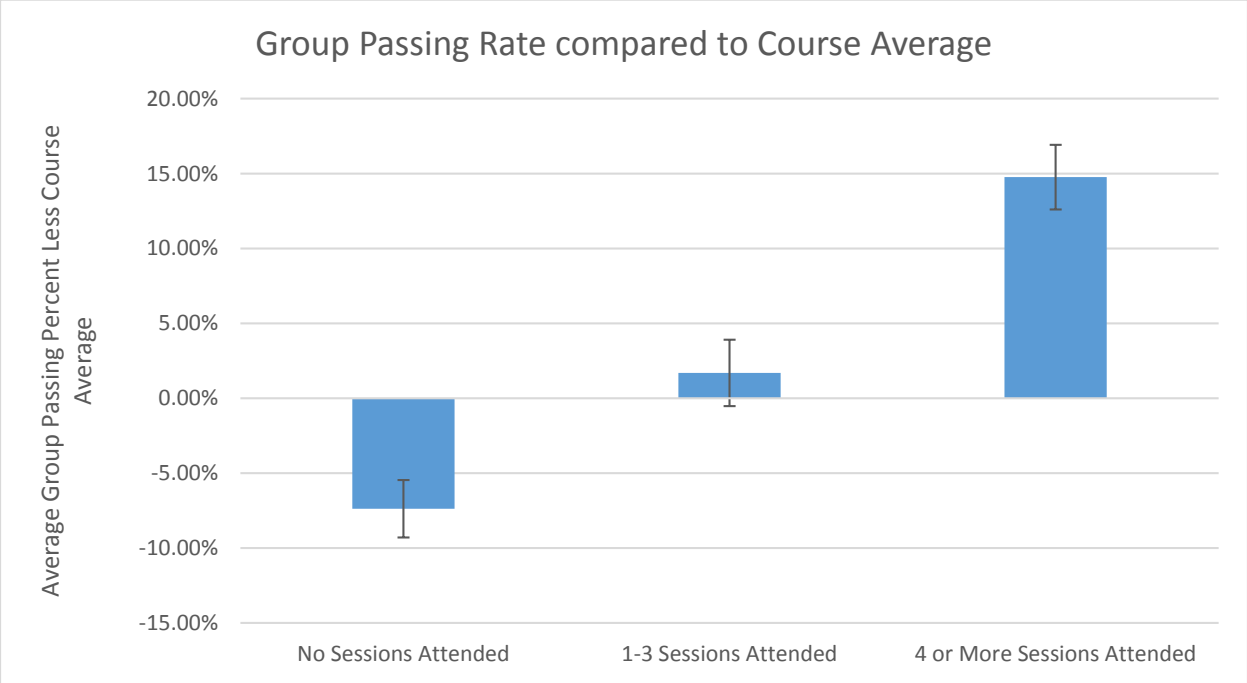

Figure 2. Average passing rates for students in all courses combined where SI was offered.

Finally, all data from every course with supplemental instruction was combined into one group (Table 3). As before, groups were made for no attendance, low attendance, and regular attendance. It was found that, students who did not attend any SI sessions were 60.62 ± 0.04 % likely to pass with an A, B, or C. Those who attended only a few sessions had a 66.92 ± 0.07 % likelihood of passing the class. Students with regular session attendance had a fairly substantial increased likelihood of passing the course, 77.41 ± 0.09 %. The difference between those regularly attending and the students who did not attend was 16.79% and is statistically significant with a p value of less than 0.0001.

SI Summary Data								
	Non-SI Students (*Attended 0 Sessions*)		**SI Students** (*Attended 1 - 3 Sessions*)		**SI Students** (*Attended 4+ Sessions*)		**Total** (*All Students*)	
	Total students:	1968	Total students:	931	Total students:	487	Total students:	3386
Grade	No. of students	Percent	No. of students	Percent	No. of students	Percent	No. of students	Percent
A	316	16%	137	15%	94	19%	547	16%
B	404	21%	222	24%	143	29%	769	23%
C	473	24%	264	28%	140	29%	877	26%
D	268	14%	128	14%	72	15%	468	14%
F	263	13%	87	9%	18	4%	368	11%
W	243	12%	92	10%	20	4%	355	10%
A,B,C	1193	61%	623	67%	377	77%	2193	65%
D,F,W	774	39%	307	33%	110	23%	1191	35%
GPA	2.14		2.23		2.48		2.22	
Confidence Interval		0.04%		0.07%		0.09%		0.02%
				Improvement in regular attendance compared to no attendance				**16.79%**
					p_i	0.64	**z test**	**-6.91**

Table 3. Summary data for all students in all courses with engineering SI

3.2 Student evaluations

Evaluation forms were distributed by the SI or by email and collected by the coordinator. Students ranked SI performance on a scale of 1 to 5 (with 1 indicating poor and 5 excellent) in the following categories: SI Leader's ability to lead discussions on important concepts, SI Leader's ability to respond to questions, SI Leader's ability to help organize content material, SI Leader's ability to create an accepting atmosphere, availability of SI session times, and helpfulness in developing problem-solving strategies (Table 4). Data collected from these surveys were extremely positive; out of the 217 forms collected, 96.9% of student responses ranked their SI as a 4 or 5 in all categories. Space for optional comments was also available and included feedback, such as “[The SI] is awesome, he made us think and explain things well. He gave us real world applications to assist in our understanding;” “[The SI is] very organized and helpful. You can tell he cares a lot about the students' understanding of the material;” “Without the SI Leader I felt like this class would have been ten times harder;” and “I am not about to make it to class most of the time, however, I have an A thanks to my SI Leader...” While the last of these comments does not reflect the intention of the program, this general opinion was noted on several of the evaluations.

SI Evaluations	Number of responses	Percentage ranked 4 or 5
Ability to lead discussion of concepts	217	99.54%
Ability to answer questions	217	98.16%
Ability to organize content/material	216	100.00%
Ability to create an accepting atmosphere	216	99.54%
Availability of session times	202	88.12%
Helpfulness in developing problems solving strategies	216	95.83%

Table 4. Feedback from optional evaluations distributed to SI attendees.

3.3 Student focus groups

An outside evaluator conducted focus groups for students who had taken courses where SI was offered. These sessions were offered in two different semesters, and students were divided into groups based on SI attendance–students who attended many, few, or no SI sessions. All students who took one of the courses listed in Table 1 were invited via email to participate in a focus group. A total of three sessions were offered for each group and lasted between 30 and 45 minutes each. The evaluator collected demographic information from each participant, but students remained anonymous, as no staff members were present for these sessions. A set of questions was prepared ahead of time to guide the discussions to try to figure out why students chose to attend SI sessions (or not). Students were also asked for their perceived value of the SI program and were encouraged to share their thoughts on how to improve it.

Overall, the evaluator found that students perceive SI sessions to be valuable; 68% of students indicated that sessions are very helpful, 30% indicated that they were somewhat helpful, and only 2% indicated sessions were not helpful. Students found value in the SIs previous student experience and appreciated tips and shortcuts as well as translations for technical aspects of the course. Students also valued the ability to work problems with SI guidance. Students suggested that the major reasons they would not attend a session include schedule conflicts, poor timing (too late, e.g.), and lack of understanding of the benefit of SI sessions. Students also commented that the SI program should be expanded to include more engineering courses.

3.4 Impact on Supplemental Instructors

SIs were evaluated and interviewed after each semester to critique the program's impact on themselves and to discuss how better to improve the program. Overall, the SIs felt that they had better mastery of the material, and they claimed to have applied techniques that they learned from being an SI to their other courses. To determine whether this had an impact on the SIs school performance, their GPAs were examined to see if there were any improvements in school success after they became Supplemental Instructors. While the number of students is too small to make statistical conclusions, it appears that there is a general positive impact on students GPAs while employed as SIs (Figure 3). Students with lower starting GPAs showed the most improvement after working as an SI. These improvements in GPA can possibly be attributed to a few of the reasons mentioned by the SIs on surveys and from focus group discussions. SIs state that they have to hold themselves up to higher standards because their peers are looking up to

them as leaders, that teaching others gives them a deeper understanding of the material, and that they have improved their communication skills.

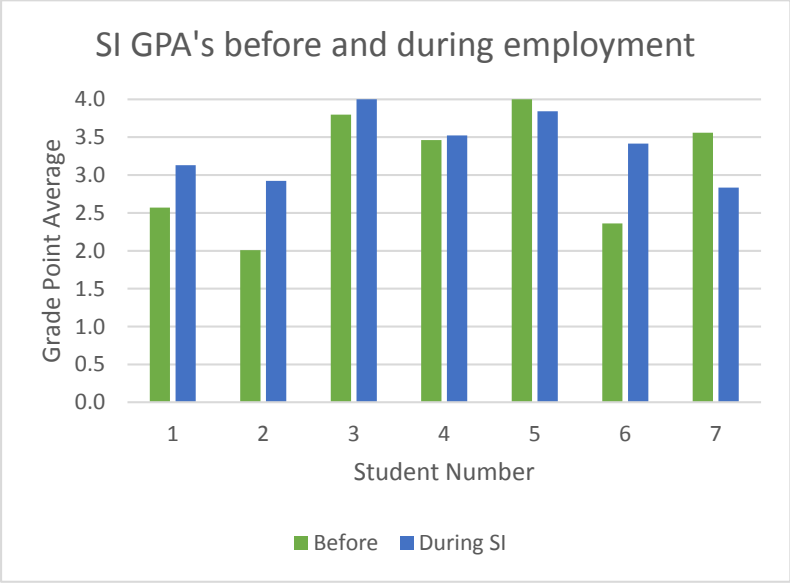

Figure 3. GPAs for Supplemental Instructors before and after becoming an SI. (Data does not include SIs with less than one semester of experience.)

3.5 Feedback from faculty members

The outside evaluator also conducted a focus group for faculty members who have taught engineering courses with an SI. All of these faculty members reported that they want to continue to have an SI in their courses and that the program should be expanded to include more courses. They also felt that the program benefits their students and that it did not require much additional effort or time on their own part. They also recognized that the success of this program is greatly dependent on selection and training of effective SIs.

4 Conclusions

The most common feedback from all groups (professors, students, and SIs) is that the program needs to be available in more courses. For this upcoming semester (Spring 2015), three additional courses were added to the SI Program. The major challenge for implementing this is cost. The results of this research are currently being used to facilitate discussions with the university's engineering departments to garner more financial support for the SI Program.

Data indicate that there are strong relationships between increased passing rates and regular attendance. However, it is difficult to tell if attending 1-3 sessions is helpful at all. When course results are averaged (Figure 2), there is no statistical improvement but if student data is averaged overall there is a slight indication of a positive trend in this range (Table 3). This may suggest that the higher enrollment classes did benefit from few sessions, but when those courses are weighted equally with lower enrollment classes there was no difference.

Almost all courses had a significant improvement in passing rates when compared to the class average. In particular, one of the hardest courses had the most significant difference: dynamics taught in the spring of 2013 had a 51% passing rate. Students regularly attending the SI sessions were 39% more likely (90%) to pass the class. While the average data and most course data is positive, there was one exception to this benefit. During the fall of 2013, circuits for electrical engineers had a negative relationship between passing rates and regular attendance. There are two potential causes for this that have been discussed. The first, and least expected, is that the SI was not effective. This SI has worked in other semesters and this trend was not observed in those semesters. This particular SI has been known to be helpful and knowledgeable about course material and has a good ability to communicate and relate to students (as per results of student evaluations and coordinator observation). However, the professor of the course was new that semester, and it is possible the SI did not adapt quickly enough. The second possibility is that the low attendance group (those who attended 1-3 sessions) performed abnormally well in the course. This could possibly be due to successful exam review sessions. This anomaly raised the overall course average, thereby making it more difficult to find a significant improvement in students who were regular attendees. Overall, students who attended any SI sessions (few and many combined) were 12% more likely to pass than students who attended no SI sessions. This strange pattern in the data was discussed with the SI, and then was brought up with all SI Leaders to get feedback about possible causes and how to prevent reoccurrence. SI Leaders agreed that both explanations were possible and the importance of attending lectures and meeting with the professors (particularly when they are new) was stressed.

There have already been several changes to the program based on these data. Some of the most valuable realizations were information already known, but failed to implement on all levels. Knowing the importance of leadership and community [16], new SI's are now more formally paired with one or two experienced SI's. These experienced SI's either teach with or observe the new SI's to give constant support, suggestions, and motivation. SI's are also now required to attend at least eight hours of leadership training every spring semester through the Society of Peer Mentors.

Data are being collected to further evaluate the program and to better remove any potential biases. Future analysis would include using predictors correlated to student success to estimate group expected grades and seeing how session attendance influences those. These predictors may include GPA, ACT, and grade performance in pre-requisite courses such as Calculus and Physics. General success will also be studied by evaluating passing rates over several years, impacts on student retention, before and after GPA comparisons, impacts on transfer students, and paired comparisons of required sequential courses that do not have SI with those that do in hopes to better understand if students more likely to pass are more likely to go to SI sessions.

4.1 Lessons learned

Implementing this program was easier than expected due to strong administrative support from the college and having found a reliable, dedicated group of students to serve as SI Leaders. While overall the implementation has been smooth, some complications did arise as would be expected. It became clear that the most important factors in creating a successful program (defined by decrease in DFW) were SI Leader selection, administrative support, and open

communication between students, SIs, professors, the coordinator, and administrators. Most complications arose from some professors being unfamiliar with the concept of Supplemental Instruction, or in a few situations with faculty members not seeing the value of SI. When the program's goal was well communicated with the professors and SIs, there were fewer problems; professors who did not originally support the SI program have since changed their mind about it. Being flexible and working with the SI Leaders was also particularly important. For example, one of our students did not meet the GPA requirements, but he had good communication skills and a passion for the class so he was allowed to work for a probationary period. He performed extremely well and raised his own GPA by nearly 1.0 since becoming an SI. Weekly training meetings for SI Leaders have also been shown to be quite beneficial and enjoyable for the SIs. These meetings help to build community among the SIs, and they give them an outlet for discussing current issues and ideas. As data such as these continue to be collected and analyzed, we hope to garner more administrative support that will both expand and strengthen the program.

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