Supplemental Instruction Pilot Program for an Introductory Electrical Engineering Course

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Abstract - **Each fall over 400 incoming Cockrell School of Engineering students enroll in the University of Texas' EE302 Introduction to Electrical Engineering, a required course for all Electrical and Computer Engineering (ECE) majors. Many students are underprepared for the rigorous curriculum and difficult coursework; as a result this course has one of the highest rates of D's, F's, drops, and withdraws ("DFQW rate") in the department. Charged with improving four-year graduation rates, the ECE department partnered with the Sanger Learning Center to provide Supplemental Instruction (SI) sessions to support the academic success of students enrolled in this course. SI is a non-remedial model that emphasizes the development of study skills through the delivery of content review sessions. A fall 2015 pilot program employed two SI leaders, provided four study sessions per week, and reached 59% of the class population with 37% attending more than one session. A mixed-methods analysis reveals that session attendance positively impacted exam scores and DFQW rates, and that students held favorable perceptions of the SI program. Analysis additionally revealed a need for further study of continued academic performance and retention within the engineering program.**

Index Terms – Academic support, Four-year graduation rates, Peer instruction, Student success and retention, Supplemental instruction.

INTRODUCTION

This paper explores the effects of SI on student performance in the EE302 Introduction to Engineering course. Specifically, this study identifies how the SI program affected students' study behaviors and in what ways the program impacted student academic performance and DFQW rates for the fall 2015 semester.

The following sections provide institutional context preceding implementation of the SI program, describe the structure of the program's organization, discuss the resulting student performance and perceptions of the SI program, and offer insights for further implementation and study.

I. Background Context

The University of Texas at Austin, the flagship institution of the UT system, enrolls approximately 40,000 undergraduate students each academic year across 18 different colleges. In 2011, UT's Task Force on Undergraduate Graduation Rates made recommendations to increase the four-year graduation rate of first time in college students from 51% in 2011 to 70% by 2016 [1]. In the Cockrell School of Engineering, this rate was as low as 31% in 2011 [2], and has responded in part by investing in student centered instruction and support models [3].

Review of the ECE undergraduate curriculum and first year student success rates revealed that in 2011-2012, the EE302 course had a DFQW rate of 23.7% [4]. A general engineering discussion section was created to support at-risk student populations enrolled in this course, and as a result DFQW rates were reduced. Looking to provide support to all student populations, the ECE department partnered with UT's Sanger Learning Center in spring 2015 to develop an SI program to launch for the 2015-2016 academic year.

II. Significance of Study

When developing the SI program in EE302, we found the body of research regarding SI in engineering in the United States to be limited. This study aims to broaden the resources available for other institutions interested in peer instructional support applied to engineering programs. By conducting this study, we investigate the efficacy of this type of academic support in engineering and conclude how we may continue to improve student academic success in this and other introductory engineering courses. Given that student participation in the SI program was voluntary, this study's findings face limitations in comparing student performance and attendance. Future studies will benefit from deeper consideration and covariation of the student's aptitude for success as it relates to attendance and performance outcomes. This initial study will set the framework for further analyses as the program gains longevity and additional data is accumulated.

III. Research Questions

To assess the magnitude of SI's impact on student achievement and identify which components of the programming are responsible for those affects, we focus this first study on our engineering SI program with the following research questions:

1. How does the SI program affect student academic performance in EE302?
2. How does the SI program affect DFQW rates for EE302?
3. What is the perceived benefit of SI by participating students?

IV. Definitions Used in Study

The following terms utilized in this study are defined according to the authors' and UT Austin's use:

- **Drop:** students may leave a course without it being noted on their transcript up to the 12th class day.
- **Fail:** a student earning below a D- has failed a course.
- **Q-Drop:** students may leave a course after the 12th class day with a "Q" noted on their transcript [5].
- **Low Socioeconomic Status (SES):** parental income reported as below $40,000.
- **First Generation:** neither parent of the student has completed a bachelor's degree or higher.
- **Underrepresented Minority (URM):** federal ethnicity reported as Latino/Hispanic, Black, Multi-Racial, Hawaiian/Pacific Islander, or Native American [4].

DESIGN AND IMPLEMENTATION

SI is an international model of academic support targeting large and historically difficult classes. Developed at the University of Missouri-Kansas City in 1973, SI's peer-assisted study sessions employ active and collaborative learning strategies to review class material and develop transferrable study skills [6]. For over 30 years, The Sanger Learning Center has coordinated SI programming at UT and supports departments within the College of Liberal Arts and the College of Natural Sciences.

I. The SI Program Structure at UT

SI staff coordinators work with partnering departments to tailor programmatic goals and procedures, employing graduate students as SI supervisors for each content area. Supervisors are responsible for the professional development of SI leaders and conduct weekly meetings, observations, and semester orientations. SI leaders are selected for their interest in teaching and learning, and may be graduate or undergraduate students depending upon departmental agreement. Leaders hold two SI sessions per week, attend weekly meetings, observe faculty and peers, administer mid-semester feedback surveys, catalog teaching documents and resources, and complete a legacy report to end the semester. Funding for SI supervisors and leaders is shared between the department and the learning center, with agreements detailed in a memorandum of understanding.

II. SI Leader Training and Development

SI leader training is completed over two days prior to the start of the semester. Orientation addresses the logistics of the program structure and job responsibilities, and the pedagogical basis of SI, diving into theoretical and practical components of active and collaborative teaching methods.

In the weekly meetings, supervisors oversee continued development of the leaders' practical skill set and pedagogical framework. SI leaders receive evaluation and feedback after being observed by the supervisor and conduct a self-reflection, which is shared with the SI coordinator at the close of the semester.

III. The Pilot EE302 SI Model

In addition to following the structure outlined above, a faculty member from the department was appointed to work alongside SI coordinators to develop the program's structure and meet weekly with the SI supervisor and leaders to identify crucial course content and best practices for discussing these concepts. The total cost of the EE302 SI pilot program, employing one graduate student at 10 hrs/wk, two undergraduate students for 8 hrs/wk, additional supplies and training costs, was ~$3,000 for the fall 2015 semester.

The objectives of the course are to introduce incoming freshman students to the basics of electrical engineering through the study of electric circuits. While the focus is only on DC circuit analysis techniques, there is a substantial emphasis on the application of these basic principles on difficult engineering problems. In an effort to structure the material, the course content is divided into three units, with a common midterm exam at the end of each unit. The emphasis of each exam is on approximately 4 weeks of instruction. Having common midterm exams allowed for a fair comparison of exam scores between different student populations based on SI attendance. Exam problems were designed to engage higher levels of thinking, more than the usual textbook or homework problems.

In the fall 2015 semester, 401 students enrolled in 6 lecture sections with about 65 students in each section. Four SI sessions were offered weekly and efforts were made to ensure that the sessions did not conflict with lecture or lab times.

IV. Summary of Current Research

Current studies of SI in engineering courses show that students attending SI sessions perform better on exams and SI attendance was positively correlated with final course grades [7]-[14]. SI attendance improves persistence in the degree program with fewer leaving the degree [9] and students attending SI complete more credits in their first year [14]. The benefits gained in SI are transferrable to non-SI courses [15] and provide benefits to the SI leaders themselves [16]. The SI program provides learning opportunities that are otherwise unavailable to students [11], and reaches greater proportions of under-represented student populations (females and minorities) [8]-[11].

Areas for caution in implementation relate to use and perceptions of the program: favorable student and faculty reception may take years to build [15] and students may become dependent upon the sessions [17].

Despite the depth of these findings, there is a lack of recent, formal study on the effects of SI programming. The majority of current studies have been presented as conference proceedings with few articles published in journals. David Arendale, former National Project Director of SI, maintains an annotated bibliography on peer cooperative learning programs [18]. In this bibliography, roughly 60 papers focus on SI and engineering students. Of those, approximately 30 papers are written regarding SI in engineering courses (as opposed to calculus or chemistry), of which 11 are from institutions within the United States.

There is need to further investigate the usage and effects of SI in engineering programming for the benefit of students' academic success, persistence and development of transferrable skills.

METHODS

This study utilizes a mixed-methods approach to collecting and analyzing data to answer the research questions. By collecting both quantitative data in the form of student grades and attendance, and qualitative data in the form of a student perception survey, we gain a better understanding of the effect SI has on the student's academic performance, and more specifically what students believe helps their academic performance as they participate in SI. This type of analysis helps us set grade and attendance benchmarks for student academic success in this course and possible ways to reach those benchmarks.

I. Quantitative Data Collection

Three forms of quantitative data were collected:

- **SI Program Usage:** at the beginning of each session, students signed in with both their name and university unique identification number.
- **Grade Data:** course grades, and pre-semester and post-semester cumulative GPAs for all students enrolled in the course were gathered. Additional information such as hours completed, transferred, failed, high school graduation percentile, standardized test scores, and predicted GPA and graduation rate were collected.
- **Student Demographics:** information on gender, race, citizenship, first-generation student status, family income, parent's education levels, probationary status, declared major, and classification was collected.

Students attending SI sessions either signed in at the start of each session with their name and their identification number or swiped their identification cards through a card reader for electronic collection. SI Leaders using the sign-in method manually entered attendance information into a spreadsheet that could later be uploaded into the SI program attendance database by the SI coordinator. For SI Leaders utilizing the swipe method, this information was automatically entered into the spreadsheet.

At the conclusion of the semester, The Cockrell School of Engineering and the academic department provided additional student grade and demographic data. All attendance, grade, and demographic data were compiled into one spreadsheet linked by student identification number. To examine the effects of SI on student academic performance, course grades were converted from categorical to continuous data as per UT's numerical grade point equivalencies [19]. As the distributions of the grades are skewed and not normal, median and inter-quartile ranges (IQR) were compared. SI attendance data, final course grades and end of semester GPA were analyzed to study the correlations between SI attendance and academic success in EE302. Analysis of SI's effects on DFQW rates included a comparison to the course's historical DFQW rate data as well as an analysis of DFQW rate by level of SI attendance.

II. Qualitative Data Collection

SI Leaders administered a student perception survey monthly, three times during the Fall 2015 semester from September through November. This survey collected information about the attendees and their use of SI, including:

- **Student Demographics:** adding to the demographic information provided by ECE and the engineering school, students provided information about their length of time at the university, previous enrollment in the course, expected grade for the course, and how many SI sessions were attended that semester for the ECE course.
- **Student Understanding of SI:** students defined the practice of SI, rated the helpfulness of the components of SI, and articulated their reasons for attending SI.
- **Use of Additional Academic Support:** students identified their levels of use of faculty and TA office hours for the course, enrollment in the GE supplement to the course, and any SI for their additional courses.

The data for each set of completed surveys was entered into a spreadsheet. Demographic information was examined and analyzed to determine the common backgrounds and their use of other academic support resources. To examine participant perceptions of SI, an initial open coding process was used to determine general themes. Then an axial coding process was used to distill and aggregate those themes. The axial codes were further analyzed to identify trends for students' perceptions of SI.

The quantitative data was used to answer research questions about the differences between students' academic performance and DFQ rates for the Fall 2015 semester and previous semesters. While this data provided course and SI administrators with a clear understanding of that difference, qualitative data was used to identify specific factors that may have influenced change. The next sections will answer our research questions by further outlining the impact of SI on student performance, what specific aspects of the SI program may have facilitated change, and recommendations for future practice and study of SI for this course.

FINDINGS AND DISCUSSION

This study uses a mixed-methodology to determine how SI affects student performance and what aspects of SI most benefit students. We ask the following research questions:

1. How does the SI program affect student academic performance in EE302?
2. How does the SI program affect DFQW rates for EE302?
3. What is the perceived benefit of SI by participating students?

Overall, a better understanding of the impact of SI and how students receive this type of programming was reached to help the program administrators determine future directions for the program and its assessment.

I. Student Academic Performance

The total course enrollment was 401 students, with 387 students completing the course. SI sessions were held on 14 weeks during the semester, and 237 students (59%) attended at least one session. In Table 1 we provide a comparison of student outcomes and demographics, based on the number of SI sessions they attended (attending zero, one, two or three, and four or more sessions). Grouping this way allows for comparable sized groups to be compared.

Grade correlation analyses and T-tests do not show significance between SI attendance and grade outcomes. Although a weak negative correlation exists between attendance and final course grades for the entire population, $r(387) = -0.08$, examining the grades of students attending 2 or more SI sessions shows a weak positive correlation, $r(146) = 0.10$. A chi-squared test indicates significant differences in the grade distributions for students attending SI 1 or more times versus those who did not attend, $\chi 2\ (7, N = 387) = 12.27, p = .007$, though more analysis is required to read into these differences, considering that differences also exist between these populations due to self-selection into the program.

A one-way ANOVA between analysis of SAT scores and SI attendance shows significant variation among SI attendance groups, $F(3, 303) = 2.84, p = 0.038$. A post hoc Tukey test indicates the SAT scores between populations attending zero and four or more sessions differed significantly, $p = .02$. Chi-squared tests show significant differences in the proportion of first generation students attending SI $\chi 2\ (3, N = 326) = 8.05, p = 0.045$. SI was highly attended by first generation students and those with lower SAT scores. Further analysis should be considered to investigate the relationships between student groups, their aptitude to succeed in the course, their self-selection for attendance, and grade outcomes.

In an effort to assess the effectiveness of the program on the lower performing student, the minimum exam score on each midterm exam of different student populations based on SI session attendance is compared. For each exam period, we considered those students who attended at least two SI sessions (over a four week period) as those who utilized the program, as opposed to the population who attended zero or one session as those who did not utilize the program. Figure 1 shows the comparison of these minimum scores. The number *N* refers to the number of students who utilized the program for each exam. These data demonstrate that those lower performing students who attended SI sessions performed substantially better than the others who didn't utilize the program.

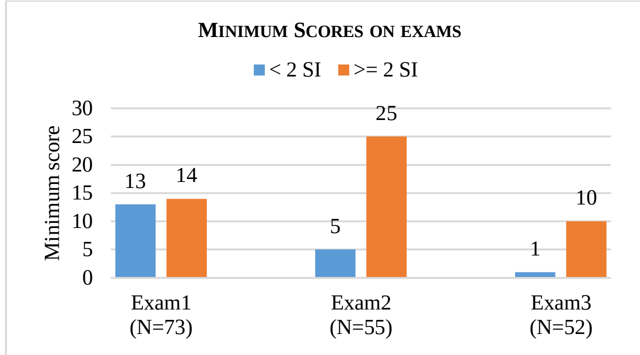

FIGURE 1
COMPARISON OF MINIMUM EXAM SCORES

While these data do demonstrate the value that the SI program brought to the EE302 freshman student experience, the median course GPA of these populations, which are listed in Table 1, did not indicate any significant improvement with more attendance. Given that the attendance was optional, and the SAT scores and predicted GPA for the higher SI attending population were lower, it is plausible that a substantial percentage of students who did not attend were indeed following lectures and not in need of additional help in the form of SI.

II. Course DFQW Rates

One of the major goals of implementing new forms of academic support for a course like this is to reduce DFQW rates in an effort to improve four-year graduation rates. The DFQW rate for the course in Fall 2015 was 10%, a 2% drop from the previous fall semester.

In Figure 2 we provide a comparison of the percentage of DFQW grades for different rates of student attendance student to demonstrate the efficacy of the SI program. The downward trend in the DFQW percentage suggests that there is a correlation between attending SI and passing the course.

While a chi-square test on the distribution of DFQW rates amongst the different attendance groups showed no significant relationship, $X^2\ (3, N = 401) = 1.89, p = .59$, there may be some relationship between SI attendance rates and DFQW rates to be investigated further with additional demographic and longitudinal data.

TABLE I
MEAN GPA COMPARISON

SI Attendance	N	% URM	% First Generation	% Low SES by Income	Median Course GPA (IQR)	Median Semester GPA (IQR)	Median Predicted GPA (IQR)	Mean SAT Score (Std Dev)
0 Sessions	164	23.81%	5.56%	16.30%	2.67 (1.34)	3.17 (1.048)	3.67 (1.05)	2059.17 (178.83)
1 Session	87	23.29%	2.74%	15.25%	3.00 (1.00)	3.33 (0.89)	3.54 (0.92)	2025.07 (178.14)
2-3 Sessions	74	30.16%	11.11%	23.40%	2.67 (1.00)	3.38 (0.64)	3.56 (0.86)	2020.67 (178.84)
≥ 4 Sessions	76	23.44%	14.06%	16.00%	2.67 (1.00)	3.15 (0.92)	3.51 (0.98)	1971.93 (195.67)

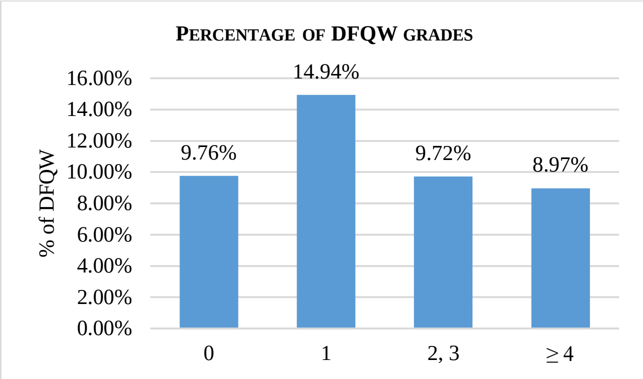

FIGURE 2
COMPARISON OF DFQW GRADES

III. Perceived Benefit to Students

Student participants' definition for SI centered on three themes: improving conceptual understanding, reinforcing class work, and providing help or support. Participant understanding of SI was generally accurate in that it is a practice designed to aid students with their understanding of course content. Table 2 summarizes students' definitions of SI and the change observed through the course of the semester.

TABLE 2
SURVEY RESPONSES: STUDENT SI DEFINITIONS (START, MID, END OF SEMESTER)

Student SI definition	Start	Mid	End
Practice that should improve their conceptual understanding	40%	23%	10%
Practice that should reinforce what is taught in class.	30%	61.8%	47.5%
Practice that provides some form of help or support.	16.7%	11.8%	32.5%

Student participants were asked to set goals for the semester. Overall themes for goals included improving knowledge of the course material, grade improvement, practicing problems, and improving critical/analytical thinking. A majority of students identified grade improvement as a goal, with that percentage increasing over the course of the semester. Table 3 lists students' goals and the change in these goals over the course of the semester.

TABLE 3
SURVEY RESPONSES: STUDENT GOALS (START, MID, END OF SEMESTER)

Student goals	Start	Mid	End
Improving content knowledge	83.3%	73.5%	10%
Improving grades	53.3%	61.8%	67.5%
Practicing problems/concepts	26.7%	32.4%	10%
Improving critical or analytical thinking	13.3%	14.7%	77.5%

The survey also asked participants to rate the helpfulness of each major aspect of the SI practice: small-group activities, large-group discussion, practice problems, concept/lecture review. Consistently, students rated practice problems the highest, with concept/lecture review just under that. Small and large group activities were considered the least helpful. Table 4 summarizes students' ratings given for each aspect of SI on a scale of 1 to 5 with 1 being least helpful and 5 being most helpful.

TABLE 4
SURVEY RESPONSES: SI HELPFULNESS (START, MID, END OF SEMESTER)

SI Helpfulness	Start	Mid	End
Small Group Activities	3.1	3.75	3
Large Group Activities	3.2	3.63	3.27
Practice Problems	4.5	4.9	4.56
Concept/Lecture review	4.3	4.57	4.41

Overall, the participants' definitions of the SI practice helping them better understand course materials are accurate. Participants also set realistic goals for their attendance of SI sessions. They indicated a desire to improve their understanding of the course material and improve their grades.

However, the participants ratings for the helpfulness of the different aspects of SI are concerning. The perceived helpfulness ratings peaked mid-semester, with end of semester ratings returning to the values given at the beginning of the semester. Future surveys should include additional question items to allow the study of these changes and identify whether there was a perceived change in quality or need for these practices. On this item, further study could also investigate a potential relationship between the perceived helpfulness ratings of different practices and differences in survey populations.

Another concern regards the comparison of these student perceptions against the traditional SI model, which uses group activities and discussions to help students better understand course materials. Participants indicated group activities and discussions were least helpful. This tension between the traditional SI model and what participants indicate was least helpful needs further examination, in addition to taking a closer look about what aspects of practice problems and lecture reviews are most helpful.

CONCLUSION AND RECOMMENDATIONS

The partnership between ECE and the Sanger Learning Center to implement SI to improve student performance and lower DFQW rates has provided ECE faculty and Sanger staff with greater insight into the effectiveness of SI programming and the type of assessment that will help with improving program outcomes. Though the difference in course grades for students attending SI versus those not attending is not significant, the decrease in DFQW rates and the perceived benefits require further, in-depth exploration.

Future directions for research and assessment include examining student outcomes based on students' predicted

GPAs when they are first admitted to the university. Comparing students who do and do not attend SI within a predicted GPA range will better tell us if the students this programming is intended to help are participating and if there is an improvement in their academic performance. It may also be helpful to study student participants' academic performance during their entire undergraduate year to see if there is a long-term effect.

In this study, student perceptions reveal that students understand the role and benefit of SI. However, these students rate activities typically deemed most beneficial as the least useful. This outcome will not only need further study; it will require SI administrators to test and develop activities and exercises not typically used in the traditional SI model. The ultimate hope for this initial study and future studies, as well as exploring and implementing variations of the SI model in the future will help faculty and staff supporting this course better understand the student experience and improve academic performance.

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