Supplemental Instruction Benefits Students in an Introductory Engineering Course

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Abstract *- Introduction to Engineering Analysis (IEA; course 20.100, Rensselaer Polytechnic Institute) is generally taken in the first semester of the freshman year and provides an integrated treatment of vector mechanics (statics) and linear algebra, also emphasizing computer-based matrix methods for solving engineering problems. The course format combines large (i.e., 80 - 100 students) lectures with weekly, smaller (40 - 50 students) recitations during which students work as teams to solve problems, assisted by the professor and/or the teaching assistant(s). IEA, therefore, incorporates active and peer-learning techniques with traditional lecture-based instructional methods. Students and faculty have been pleased with the additional teamwork and problem-solving practice provided by the recitation sections; however, the recitations are not a panacea for the many special challenges inherent in teaching a first-semester, freshman-level course. For example, students who performed well in high school classes, while exerting minimal effort, may not possess study skills which are appropriate for a rigorous college environment. Moreover, engineering problem solving is often a totally new mental exercise for college freshmen, even for students who excelled in high school math and science classes. Therefore, the Learning Center at Rensselaer initiated a series of Supplemental Instruction (SI) sessions for IEA students in the Fall of 1996.*

Supplemental Instruction

SI, originally developed in 1973 by Deanna Martin at the University of Missouri-Kansas City [Martin and Arendale, 1994], is a program designed to enhance student mastery of course materials and to encourage effective learning and study skill strategies [Arendale, 1994]. SI sessions provide students with the opportunity to attend voluntary, structured, interactive learning sessions centered around a course without disrupting or altering the lecture, recitation, and/or laboratory sessions for a course. While SI has been successfully integrated into college courses such as chemistry [Lockie and Van Lanen, 1994], biology [Zerger, 1994], and mathematics [Kenney and Kallison, 1994] as well as medical school courses [Widmar, 1994], the potential benefits associated with offering SI for engineering courses have not been examined in detail. Therefore, we modeled our SI program for IEA after successful SI programs for other courses.

SI Personnel Roles

Three key personnel were crucial to the success of our SI program: the SI leader, the SI supervisor, and the course instructor. The SI leader was an undergraduate student who had mastered course subject matter, completed SI training, and was considered acceptable by both the Learning Center and the course instructors. The SI leader attended all course lectures and conducted two to three one-hour SI sessions per week. The SI leader was viewed by the students as an "ideal student," who was approachable, knowledgeable, and available to answer questions. The main goal of the SI leader in the program was to facilitate questions and answers from the SI group and, therefore, allow students to assist each other in problem solving.

The SI supervisor, a learning skills academic support team specialist with extensive knowledge concerning effective study skill techniques, was responsible for orienting the SI leader with the SI program and continually training the SI leader as the semester progressed. Initial training simulated ineffective or unproductive SI sessions (such as sessions involving blatantly uncooperative students, or students who ask the SI leader to regurgitate answers of assigned homework problems). In this manner, the initial training allowed the SI leader to identify group dynamic problems, adapt, and incorporate techniques necessary to result in a favorable group learning environment. Continual training consisted of direct monitoring of SI sessions by the SI supervisor. At the conclusion of each monitored session, the SI supervisor offered constructive criticism on ways to keep the learning process both informative and enjoyable while emphasizing necessary study skill lessons. An additional portion of the semester-long training process involved periodic meetings between all participating SI leaders, in which common

group dynamic problems and possible future session activities were discussed.

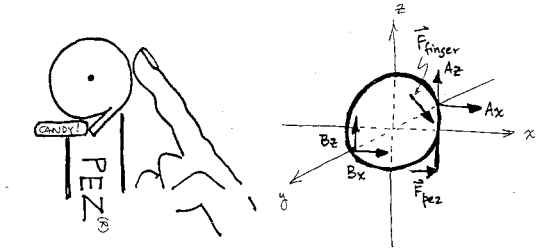
The role of the course instructor was primarily one of passive support: the instructor encouraged students to attend SI and permitted the SI leader to make announcements in class regarding SI meeting times and benefits of SI participation. Meetings between the SI leader, SI supervisor, and the course instructor were conducted periodically throughout the semester, providing crucial feedback for all SI personnel.

SI Sessions

Each session usually began with the students and the SI leader constructing and discussing a review sheet composed of previous lecture material. If a question was asked during this period, the SI leader acted as a facilitator until the group of students answered the question. After the group conducted a short review of the course material, a previously-prepared list of relevant questions (*i.e.*, an informal quiz) was assigned by the SI leader. In the beginning of the semester, the informal quiz was composed solely by the SI leader, but as the semester progressed, students were asked to contribute questions. Consequently, students learned to predict exam topics and on several occasions actual exam questions were predicted by students during the SI sessions.

The informal weekly quizzes stressed mathematical and problem solving concepts through mandatory SI attendee participation. Since an attendee explained to the remainder of the group how a solution was obtained, student content understanding was enhanced. Students were strongly encouraged to write specific problem solving steps in English sentences, rather than in mathematical symbols, for each problem presented to the group. Frequently students asked if they had defined an engineering term correctly, but instead of supplying an answer, the SI leader posed the question to the group and facilitated until the correct answer was reached. In this fashion, students compiled an extensive engineering vocabulary that aided them first in problem understanding and subsequently in problem solving. An informal group dynamic was established during the SI sessions, therefore a comfortable atmosphere was presented for students to ask and address all questions. Because questions and explanations were posed by a student, they tended to be more comprehensible to other students (with similar frames of reference) than textbook or instructor explanations.

Other session activities varied throughout the semester according to the needs of the students: students composed (and completed) a mock exam, played "Jeopardy"-style fact-recall games, or completed sample exams to simulate the anxiety present during a testing situation. For example, during one well-received SI session each student was handed a "PEZ" candy dispenser; the students then drew free-body diagrams and solved three-dimensional force and moment problems regarding the "PEZ" candy dispensers (Figure 1).



Side view : finger pulls on Pez character head, candy is ejected.

Free-body diagram.

If Fpez, or the force pushing the Pez candy out of the container, equals 0.004 N, find the reactions at the journal bearings A and B and the "finger force" required to get the Pez candy out of the container. Note that the "finger force" acts at a 45 degree angle from the z-axis, in the z-x plane.

Figure 1 : SI "PEZ" Informal Quiz
Informal quizzes were frequently utilized to simulate an exam situation in the SI sessions; for the above informal quiz, each student was handed a "PEZ" candy dispenser and given time to solve the problem before presenting their answer to the remainder of the group.

Study skill strategies were continuously integrated into the SI sessions throughout the term and focused on improving students' textbook reading, lecture notetaking, time management, memory enhancement, stress management, and test taking skills. In this manner, SI provided an important learning experience (particularly for freshmen) since, in a traditional learning situation, the course instructor focuses primarily on subject matter rather than relevant study skills. These skills tend to be lacking in freshman engineering students but are crucial to the success of a student in an engineering program.

Methodology and Data Analysis

SI sessions for IEA were offered on a pilot basis through the Learning Center at Rensselaer, during the Fall semester of 1996. One-hour sessions were held twice a week, by an undergraduate SI leader, following the SI format outlined above in the Supplemental Instruction section. All IEA students (approximately 400 students) were informed about and welcomed to SI sessions, while one IEA class (consisting of 90 students) was designated a "focus class" for the purpose of quantitatively evaluating the effectiveness of the SI program.

To determine the student demographics of SI attendees, students in the focus class who received either a "D" or an "F" on an IEA exam were designated "high-

risk," while students who received a "C" on an exam were designated "at-risk." After the exams, each high-risk and each at-risk student had a private conference with the course instructor, during which the instructor recommended that the student attend SI.

The Learning Center monitored SI attendance, and, after the semester was over, used course grades (and exam grades from the focus class) to quantitatively evaluate the effectiveness of the SI program. Moreover, just before the end of the semester, a survey was administered to students in the focus class, to determine student perception of the SI program.

Standard statistical methods were utilized in the data analysis to compare the final course grades of SI participants to non-SI participants: Student t-tests were employed for comparing final course grades and chi-square tests were utilized for comparing the percentage of A and B final course grades to the percentage of D and F final course grades.

RESULTS AND DISCUSSION

Total Class

The SI sessions were well attended throughout the semester, with large increases in attendance prior to each of the three exams and before the final exam (Figure 2). 23 % (N=82) of the total class enrollment attended at least one of the 21 SI sessions, and the mean number of sessions attended by an SI participant was 3 (Table 1). The mean size of an SI session was 13 students and the total number of contact hours for participating students (*i.e.*, the mean size of an SI session multiplied by the total number of SI sessions offered during the term) was 273 hours (Table 1).

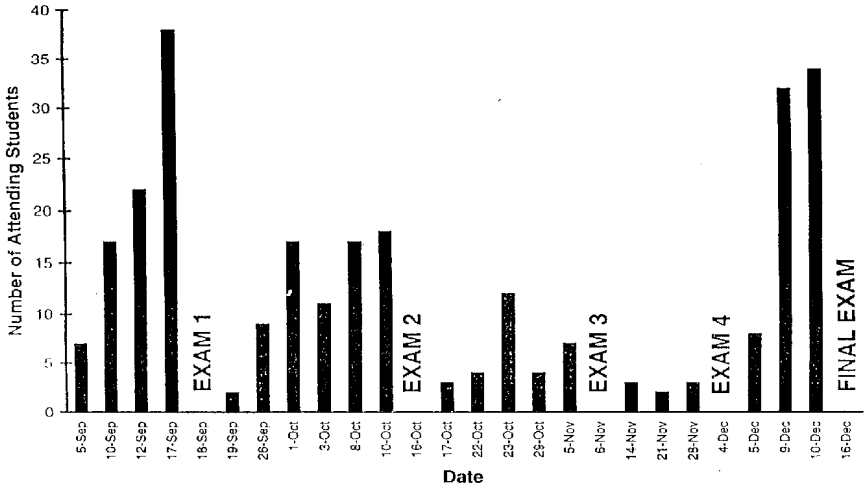


Figure 2 : SI Attendance Throughout the Semester
SI sessions were well attended throughout the semester, with large increases in attendance prior to each of the three exams and before the final exam.

Table 1 : SI Summary Information

Total Course Enrollment (Students who appeared on the final class roster after drop/add)	362
Number of SI Sessions Offered During the Term	21
Total Number and Percentage of Students Attending SI (Unduplicated headcount)	82, 23 %
Total Contact Hours of SI Participating Students	273
Mean Number of Sessions Attended by SI Participants	3
Mean Size of SI Sessions	13

Focus Class

43 % (N=39) of the enrolled students in the focus class attended the SI sessions, making the SI attendance higher for the focus group than for the overall class. This may be because the SI leader attended the focus class lecture and made direct announcements to the focus class concerning SI, while for the other IEA sections the respective professors made class announcements concerning SI, and therefore the sessions may not have been emphasized as frequently. In addition, for successful SI implementation, the enrolled students must be able to identify the SI leader as an approachable model student, which can only occur for the class the SI leader is attending.

Course material comprehension and university engineering student retention were evaluated for the focus group by examining final course grades of SI and non-SI attendees (Table 3). The mean final grade point average was significantly ($p < 0.025$) greater for SI (3.13) than non-SI (2.67) attendees, indicating an increase in course material comprehension for SI attendees. An increase in university engineering student retention is also predicted by the statistically ($p < 0.01$) lower percentage of D and F final grades for SI (0 %) than non-SI (18%) attendees [Martin and Arendale, 1994].

Table 3 : Focus Class SI and Non-SI Final Grade Comparison

	SI Group N = 39	**Non-SI N = 51**
Grade	**Percent**	**Percent**
A	36 %	29 %
B	41 %	33 %
C	23 %	20 %
D	0 %	10 %
F	0 %	8 %
Combined A and B Final Grades	77 %	62 % **
Combined D & F Final Grades	0 %	18 % **
Grade Point Average	3.13	2.67 *

* statistically significant at $p < 0.025$; ** statistically significant at $p < 0.01$.

In order to evaluate the effect of SI attendance on student comprehension of subject material, the final grades of those students who attended SI were compared to those who did not (Table 2). Students who attended SI received significantly ($p < 0.1$) higher mean final grade point average (2.74) than students who did not attend SI (2.49), thus indicating an increase in course material comprehension for SI attendees. The percentage of students who received a final grade of D or F was correlated with SI attendance as a measure of attrition rate, since astudent who receives a final letter grade of D or F in a college course is less likely to continue his/her program of study than a student who receives a higher final course grade [Martin and Arendale, 1994]. Students who attended SI received a significantly ($p < 0.01$) less percentage of D and F final grades (12 %) than students who did not attend SI (24 %), thus predicting an increase in university engineering student retention for SI attendees.

Table 2 : Total Class SI and Non-SI Final Grade Comparison

	SI Group N = 82	**Non-SI N = 197**
Grade	**Percent**	**Percent**
A	23 %	23 %
B	40 %	33 %
C	25 %	20 %
D	12 %	16 %
F	0 %	8 %
Combined A & B Final Grade	63 %	56 % **
Combined D & F Final Grade	12 %	24 % **
Grade Point Average	2.74	2.49 *

* statistically significant at $p < 0.1$; ** statistically significant at $p < 0.01$

A student was considered an SI attendee if he/she attended one or more SI sessions. This procedure was implemented following the work of Martin and Arendale [Martin and Arendale, 1994] and since study skills are an integral part of every SI sessions, a student may receive immediate suggestions on techniques to improve his/her study skills, thus benefiting from just one SI attendance. In addition, students who only attended SI directly before an exam may

have received enough help to enhance their performance for that exam, and possibly for the remainder of the semester.

Early and Frequent SI Attendance

To further elucidate the benefits of attending SI, the first exam grades of SI and non-SI attendees were compared. Before the first exam, 39 % (N=35) of the focus group attended SI and subsequently received a significantly (p < 0.01) higher score on the first exam compared to students who did not attend SI, suggesting that there may be immediate benefits of attending SI sessions early in the semester.

To evaluate the benefits of attending SI frequently, course grades for the focus class were plotted as a function of number of SI attendances (Figure 3). The more times a student attended SI, the more likely he/she was to receive a higher grade. In fact, all students who attended at least 4 SI sessions throughout the semester received a final course grade of an A or a B (Figure 3).

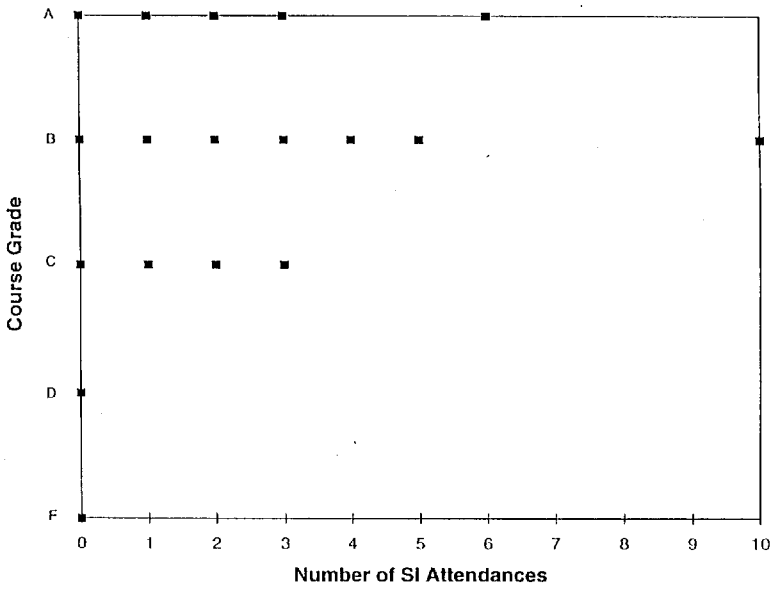


Figure 3 : Course Grade as a Function of SI Attendance
The more times a student attended SI, the more likely he/she was to receive a higher grade. Students who attended at least 4 SI sessions throughout the semester received a final course grade of an A or a B.

These data indicate that students who attended SI sessions early (before the first exam) and frequently (at least 4 times throughout the semester) earned higher course grades than students who attended SI late in the semester and/or infrequently. From these results it is unclear whether the students who were attending SI would have excelled without it, or whether SI was helping students to excel. It therefore became necessary to know SI demographics before making any solid conclusions about the benefits of attending SI.

To determine the demographics of SI attendees, focus group "high-risk" and "at-risk" students were designated after each exam as described in **Methodology and Data Analysis**. Overall, 30 % (N = 8) of students ever designated as "high-risk" and 41 % (N=15) of students ever designated as "at-risk" attended the SI sessions at least once. This indicates that the majority (66%) of the focus class SI attendees (N=35) was composed of "at-risk"(43%) and "high-risk" (23%) students. Furthermore, these data show that "at-risk" students were more likely to attend the SI sessions than their "high-risk" counterparts.

To specifically evaluate the impact of SI attendance on comprehension of course material by "high-risk" and "at-risk" students, final course grades of SI and non-SI students who were ever designated as "high-risk" or "at-risk" were compared. For the focus group, there were 37 students designated as "at-risk" at some point throughout the semester; 15 of these students attended SI sessions and received a significantly (p < 0.01) higher mean final course grade (2.6) than "at-risk" students who did not attend the SI sessions (2.18). Of the 17 students designated as "high-risk" throughout the semester, 8 attended SI and received a

significantly ($p < 0.01$) higher final course grade (2.38) than the "high-risk" students who did not attend SI (1.58). Therefore, students who were ever classified as "high-risk" or "at-risk" and attended at least one SI session received higher course grades than students who were ever classified as "high-risk" or "at-risk" and did not attend SI.

Unfortunately, low SI attendance by "high-risk" students immediately after the first and/or second exam hindered detailed tracking of targeted students. For example, 7 students were identified as "high-risk" after the first exam; one student subsequently attended SI sessions and received a final course grade of B, while the remaining six non-SI attendees received final letter grades of: F, F, F, D, D and one withdrew from the course.

From the above, it is apparent that a "high-risk" performance on the first exam correlated with a predicted poor performance in the course overall with the exception of the "high-risk" student who attended SI. While again, the small sample size precludes drawing concrete, statistical conclusions from this observation, it can be inferred that SI did not effectively reach the student population most at need (the "high-risk" students).

SI Effectiveness Evaluation

Student Evaluation

SI attendees have embraced the sessions, giving them a 4.7 on a scale of 1 (not helpful) to 5 (very helpful) on an SI end-of-the-term evaluation (Table 5). The students commented that informal quizzes were very beneficial to their final understanding of a particular topic. Students also liked the informal nature of the sessions, the fact that the SI sessions correlated well with what was being covered in class, and that they were given feedback by fellow students on how well they understood the course material.

Table 4 : Focus Class "High-risk" and "At-risk" Final Course Grades

* statistically significant at $p < 0.01$

	Course Grade	
	SI	**Non-SI**
Ever At-Risk	2.60	2.18*
Ever High-Risk	2.38	1.58*

Table 5 : Focus Class SI End-of-the-term Survey

Question	**Average Score (1) not helpful ..... very helpful (5)**
For students who attended one or more SI session: (N=29)	
1) How helpful were the SI sessions to you ?	4.7
2) I felt the SI leader was genuinely concerned about my class progress	4.6
3) SI sessions encouraged me to adopt more effective study strategies	4.2
4) What was your reason for attending SI ?	
Didn't understand a particular topic	27.5 %
Wanted feedback on how well I understood the material	31 %
Falling behind in class	27.5 %
Didn't do well on exams	7 %
Fear of science classes	0 %
Curious as to what SI was	7 %
For student who did not attend at least one SI session: (N=26)	
5) What was your reason for not attending SI ?	
Time conflict	12 %
Didn't feel it was necessary	44 %
Didn't think it would be helpful	16 %
Intended to, but couldn't find the time	16 %
Not motivated to put extra time into the class	12 %

A major complaint concerning SI was that some sessions were too crowded and there was not ample time to cover all the necessary material. It seemed that most students would have appreciated a longer SI time duration and/or additional SI leaders; possibly a 1.5 - 2.0 hour session twice a week, with two SI leaders, would have been more beneficial. Most of the students who did not attend SI but responded to the end-of-semester survey did not feel supplementary help was necessary for this specific course, although the same students indicated that they would attend SI if it were offered in a more difficult class (Table 5).

Course Instructor Evaluation

The SI program was well received by the course instructors, who were exceptionally pleased with the feedback received from the SI leader throughout the program. The SI leader communicated periodically with the course instructor(s) when the class did not fully comprehend a lecture topic. This allowed the instructor(s) to allocate time in the next lecture or recitation for further review of the subject. An excellent relationship was established between the SI leader and the focus class course instructor which resulted in cooperative planning of key SI activities.

SI Leader Evaluation

The SI program, in addition to offering monetary rewards for undergraduate ($585 semester stipend) or graduate ($720 semester stipend) SI leader positions, aided the SI leader in further course material understanding. The SI leader involved with this study discovered that, although she was confident of the subject matter prior to the start of the program, she now has a deeper appreciation for the course material. The SI leader also excelled in the classes she was taking because she was continually reviewing fundamental engineering concepts. In addition, the SI leader continued to develop her communication, teaching and leadership skills throughout the program. Although a significant time commitment must be made by the SI leader throughout the semester (approximately 8 - 10 hours a week), the SI leader was pleased to help fellow students comprehend course material.

CONCLUSIONS

Supplemental Instruction was successfully implemented by the Learning Center at Rensselaer Polytechnic Institute for an introductory engineering course (IEA), as indicated by two main results: 1) students who ever attended SI received significantly ($p < 0.1$) higher course grades than did students who never attended SI, and 2) students who attended SI were less likely to receive a final course grade of D or F, and were less likely to withdraw from the engineering program. However, approximately half of the students who had the most to gain from attending SI (*i.e.*, "high-risk" and "at-risk" students) chose not to attend SI, even when encouraged to do so. Further outreach programs/strategies may be necessary to provide these students with the academic support they need, or to motivate these students to attend SI.

In the present study, students were more likely to participate in the SI program when the SI leader attended their course lectures and when the course instructor openly and frequently expressed support for the SI program. Students who began attending SI sessions early in the semester, and who attended frequently thereafter, benefited the most from the SI experience. Because of the positive student and faculty feedback received throughout the semester, and because the study skills emphasized in SI sessions (which many freshman engineering students lack and are crucial to a student's academic success) expanded SI sessions for IEA are planned for future semesters.

REFERENCES

Arendale, D., "Understanding the Supplemental Instruction Model." In Martin, D. C., Arendale, D. (eds.) *Supplemental Instruction : Increasing Achievement and Retention*. New Directions for Teaching and Learning, no. 60. San Francisco: Jossey-Bass, 1994.

Kenney, P. A., Kallison, J. M., "Research Studies on the Effectiveness of Supplemental Instruction in Mathematics" In Martin, D. C., Arendale, D. (eds.) *Supplemental Instruction : Increasing Achievement and Retention*. New Directions for Teaching and Learning, no. 60. San Francisco: Jossey-Bass, 1994.

Lockie, N. M., Van Lanen, R. J., "Supplemental Instruction for College Chemistry Courses" In Martin, D. C., Arendale, D. (eds.) *Supplemental Instruction : Increasing Achievement and Retention*. New Directions for Teaching and Learning, no. 60. San Francisco: Jossey-Bass, 1994.

Martin, D. C., Arendale, D. (eds.) *Supplemental Instruction : Increasing Achievement and Retention*. New Directions for Teaching and Learning, no. 60. San Francisco: Jossey-Bass, 1994.

Widmar, G. E., "Supplemental Instruction: From Small Beginnings to a National Program" In Martin, D. C., Arendale, D. (eds.) *Supplemental Instruction : Increasing Achievement and Retention*. New Directions for Teaching and Learning, no. 60. San Francisco: Jossey-Bass, 1994.

Zerger, S., “Supplemental Instruction in Content Areas: Humanities” In Martin, D. C., Arendale, D. (eds.) *Supplemental Instruction : Increasing Achievement and Retention*. New Directions for Teaching and Learning, no. 60. San Francisco: Jossey-Bass, 1994.