Using Student Instruction to Increase Retention in Engineering

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Using Supplemental Instruction to Increase Retention in Engineering

Abstract - The Citadel School of Engineering was challenged by the College President in 2011 to retain and grow the number of engineering students in respective program. The concept of increasing the number of engineering students thereby increasing the number of graduates was analyzed as part of strategic planning for the School of Engineering. Key indicators found during this study were increased marketing, preparedness of the incoming students, retention of those who arrive, and the addition of new programs. This paper will only focus on the retention of those students who arrive each year as freshman. The School of Engineering used a simple suggestion by one of its faculty concerning a well-known concept such as SI, supplemental instruction, to improve retention of engineering freshman by nearly 20%. This paper will establish the conditions prior to the implementation of SI, the challenges in implementing and sustaining SI, and the retention results that are greatly influenced by SI.

Introduction

At colleges across the country many freshmen students declare a major prior to arriving on campus and their course schedule is predetermined by that intended major. For engineering majors they start out in calculus, chemistry and physics courses before entering their engineering courses. Often these time intensive and challenging courses pose as a hurdle toward obtaining the desired engineering degree.

Institutions have been studying factors that influence persistence vs. attrition rates in the engineering major. Student persistence has been credited to a wide variety of programs including the development of introductory engineering courses, addition of supplemental instruction to freshmen and sophomore level classes, and faculty mentorship. Attrition factors also seem to draw back to students’ grades prior to attending college in math, science, and English as well has their high school grade point average [1].

The intention of this study was to focus on implementing a Supplemental Instruction program into the freshmen and sophomore level engineering courses, which also included prerequisite courses in chemistry, mathematics and physics. By making this type of strategic effort it was predicted to improve the overall retention of freshmen engineering students.

Background

Retention initiatives play a critical role in keeping students in the engineering major. Approximately half of students will decide to leave the major before the start of their sophomore year [2]. The decision to leave the engineering major can be based on many factors including: if a student is failing courses in their major, motivation to do well in school, external influences (peers/parents) and change in attitude about the major. There are some students who view the major as a means to make a competitive salary upon graduation and others who have a true passion for the study of how engineering connects the world.

Supplemental Instruction (SI) was created to assist students in high risk courses by offering sessions throughout the semester that focus on a deeper comprehension of the course material.
presented each week. The SI program is voluntary for students to attend, although some
professors offer the incentive of extra credit to lure students to go to sessions. All sessions are
free to attend and are conducted in a group atmosphere rather than a one-on-one tutoring style.
Each SI session is led by a student (SI Leader) who has previously completed the course, has
shown proficiency by receiving a B or better in the class, and should attend one of the instructors
sessions. The sessions are available on a drop-in basis and convene twice a week in the evening
between the hours of 6 – 10 p.m. By offering SI on a weekly basis students are able keep up
with difficult topics in an active learning environment. As McGuire noted “SI is an important
mechanism for introducing students to the learning process, engaging them in collaborative
learning activities, and providing a collegial environment that increases motivation to engage in
learning” (p.4) [3].

The SI Leaders who run the weekly sessions model learning ability and work closely with the
faculty member instructing the course to identify areas for improvement by reviewing
homework, quizzes and tests throughout the semester, while also observing student performance
with difficult concepts during class. It is important that SI leaders are skilled at not repeating the
professor’s lecture, but rather mirroring the content so students are able to see the material
presented in a way that varies from the book and lecture [4].

The Citadel is a public four-year college made up of approximately 2,300 undergraduate students
who are members of The Citadel Corps of Cadets – therefore, the freshman year has even more
stress than normal. There are 17 majors and 32 minors offered including Bachelor of Science
degrees in Civil and Environmental Engineering (CEE) and Electrical and Computer
Engineering (ECE). In the spring 2014, a Bachelor of Science in Mechanical Engineering (ME)
will be added to the curriculum. Both CEE and ECE majors begin their studies in introductory
engineering courses alongside math and science courses. CEE offers CIVL 103, Introduction to
Civil Engineering and ECE offers ELEC 106, Fundamentals of Electrical Engineering. Every
freshman student that has declared one of these majors is required to take the introductory course
during their first semester at the college.

When evaluating retention in the School of Engineering it was important to understand the
demographic of our incoming first-time freshman at The Citadel. Shown in Figure 1 are first-
time freshman student average high school Grade Point Ratios (GPR). In 2011 the GPR took a
significant 0.10 jump and from that point has continued to increase. The continued increase in
average GPR does show that The Citadel is able to be selective with incoming freshmen
students. Conversely Figure 2 shows a decrease in first-time freshman student average SAT
scores. Since the average SAT scores are currently declining, it could be a partial indicator of
why students are having difficulty in the required engineering math and science courses
(Calculus I, Physics I & Chemistry I). However, an examination of how engineering students
scored on the math portion of the SAT would be required to determine if that hypothesis is valid.
This has not been completed due to the recent announcement of changes in the SAT.
Figure 1: First-time Entering Freshman Average High School GPR Data Collected by the Office of Institutional Research

![Bar chart showing the average high school GPR for first-time entering freshmen from 2004 to 2013. The GPR values range from 3.05 to 3.6. The years 2004 to 2013 are displayed on the x-axis, and the GPR values are displayed on the y-axis.]

Figure 2: First-time Entering Freshman Average SAT Score Data Collected by the Office of Institutional Research

![Bar chart showing the average SAT score for first-time entering freshmen from 2004 to 2013. The SAT scores range from 1055 to 1110. The years 2004 to 2013 are displayed on the x-axis, and the SAT scores are displayed on the y-axis.]

Figure 1: First-time Entering Freshman Average High School GPR
Data Collected by the Office of Institutional Research

Figure 2: First-time Entering Freshman Average SAT Score
Data Collected by the Office of Institutional Research
Motivation for Supplemental Instruction

In an effort to increase the number of science, technology, engineering, and mathematics (STEM) graduates at The Citadel, The President tasked each STEM department in 2011 with increasing overall enrollment by 10% by 2015 as part of The Citadel’s Strategic Initiative [5]. As a result, the strategic plan of School of Engineering included a methodology to increase the overall number of engineering enrollments, thereby increasing the number of engineering graduates from the college. The methodology involved several areas of approach including effective marketing, an increased level of preparedness of incoming students, the addition of new engineering programs, and the retention of those students that arrive. This paper focuses specifically on the retention efforts in the School of Engineering at The Citadel. In years preceding 2011, high attrition rates beset the departments of the School of Engineering. Especially high attrition rates from the fall semester of freshmen year to the spring semester of freshmen year and from the spring semester of freshmen year to the fall semester sophomore year concerned the engineering faculty and administration. The lack of freshmen retention demonstrated the critical need for the establishment of a strong retention initiative within the School of Engineering. As a result, the School of Engineering and the Academic Support Center pursued the implementation of a robust Supplemental Instruction program targeted at all relevant freshmen STEM courses.

The Citadel selected to target STEM courses to vary from previous university research that focused strictly on engineering courses. In 2001, the University of North Carolina at Charlotte studied the application of SI to sophomore-level engineering courses including how it was developed, implemented, assessed and improved over the span of five years [6]. More recently in 2011, Mercer University focused solely on engineering courses they determined were the “weed-out” classes [7].

Keeping in mind the struggles that students were facing in engineering courses, The Citadel selected to review the D, F and Withdraws grades (DFW) in courses that were prerequisites to engineering courses. Beginning in fall 2012, it became apparent that many of the prerequisite classes to get into engineering courses were some of the most troubling for our engineering students, therefore resulting in high DFW rates.

As shown below in Figure 3, a comparison of DFW rates for Fall 2012 and Fall 2013 for courses with SI session demonstrates a decrease in the DFW rates in Chemistry, Math and Physics courses, whereas Engineering courses had a 7% increase. The decrease can be attributed to the impact of having SI Leaders in a majority of the math and science sections offered at The Citadel. The increase indicates the need to encourage poor performing students to attend SI (initial grade vs. attendance comparisons) and possibly more engineering courses with an SI Leader assigned.
History of Academic Support Services at The Citadel

The Citadel initially established an Academic Support Center in 1984, then called The Writing Center, to help reduce the high failure rate in English 101. The center expanded its efforts to offer a variety of services to encourage student success. In 2011, the Academic Support Center included a Writing Lab, a Learning Strategies program, a Subject Area Tutoring (S.A.T.) program, a Mathematics Lab, and an SI program. The Writing Lab provides support for students in the construction and execution of any written assignments. The Learning Strategies program assists students struggling with essential study skills such as time management, effective note taking, and controlling test anxiety. The Subject Area Tutoring program allows students to receive one-on-one assistance from a professional tutor in many subjects ranging from history and foreign language to biology and chemistry, and the Mathematics Lab provides drop-in assistance with all mathematics through Calculus II [8]. In 2011 the SI program, established just five years prior, existed primarily in foreign language, history, English, and biology courses. The Academic Support Center experienced tremendous success in each of its programs and looked to expand in the fall of 2011.

Expansion of SI Program

The Civil and Environmental Engineering Department at The Citadel first recognized a need for SI in its courses in the fall of 2011. The Mechanics of Materials course (CIVL 304), an essential and fundamental course to all civil engineers, proved difficult for many students. Therefore, the department selected a student leader and initiated SI in its two sections of CIVL 304.

Figure 3: Comparison of DFW Rates during Fall 2012 and Fall 2013
Data Collected by the Office of Institutional Research

![Comparison of DFW rates for Fall semesters](image-url)
average, approximately 15% of the class attended each nightly study session. The success of the SI program that semester encouraged an expansion for the spring of 2012 where SI also included two sections of Engineering Mechanics – Statics (CIVL 202) and two sections of Structural Analysis (CIVL 309).

Therefore, when the School of Engineering began strategizing to improve retention in the freshmen year, the establishment of a robust SI program quickly ascended as the most effective solution. The benefits of an SI program included the impact on retention while potentially enhancing overall quality of engineering student performance and a strong sense of community among all engineering students. Therefore, over the summer of 2012, the School of Engineering sought to create an SI program that supported all freshmen and sophomore engineering students in all required courses. Quickly, time and resource constraints narrowed the scope of this vision. Ultimately, the School of Engineering settled on a program that used SI leaders in all 5 sections of Precalculus (MA 119), all 3 sections of Calculus (MA 131), provided one hour of drop-in chemistry tutoring, and 1 hour of drop-in English and history tutoring in the engineering buildings during The Citadel’s Evening Study Period (ESP) each night.

Even with the narrowed scope, many challenges existed regarding implementation of the SI program. First, never before had The Citadel employed this quantity of undergraduate students (9 total) as part of any tutoring initiative (employed graduate students in the past). Not only did the program require that the students be identified and selected quickly by the School of Engineering, the Academic Support Center had to work diligently to clear each of these students for employment. Also, a program such as this had not previously existed for freshmen students. A deliberate marketing and promotion plan had to be created to ensure student awareness. Therefore, concise handouts including information for Academic Support Center services and the time, location, and leader for each SI session were distributed to all freshmen STEM students at The Citadel. Additionally, the SI leaders themselves promoted the program frequently within the classes they attended (new concept). Finally, the student leaders had to be educated and provided the proper vision in order for the program to be a success. As a result, the student leaders were trained prior to the start of the semester and most leaders attended weekly lunch meetings each Friday for further training and discussion to reinforce the vision and purpose of SI.

During these meetings SI leaders were able to discuss issues they were facing regarding attendance at sessions or tips on presenting material to students in an effective manner.

Topics covered at the meetings included:

- Structure of an SI Session
- Learning Strategies
- Group Work Strategies
- Role Playing Scenarios
- Time Management
- Attendance Strategies
- Redirecting Questions to Students
- Test Taking Tips
- Managing Stress and Anxiety
The success of the program during the fall of 2012 allowed it to expand once again for the spring of 2013. At this time, the School of Engineering offered SI support in all sections of mathematics through differential equations, all sections of chemistry, all sections of physics I and II, all sections of CIVL 202, all sections of CIVL 309, all sections of Computer Applications for Electrical Engineers (ELEC 206), and all sections of Circuits II (ELEC 202). Similar offerings were held for the fall 2013. Table 1 contains a complete listing of the number of all relevant freshmen, sophomore, and junior courses and the number of sections that contained SI for fall 2012 through fall 2013. Figure 4 summarizes the total number of sections offered and covered by SI.

Table 1 – Summary of the Number of Sections of all Relevant Mathematics and Science Courses Offered and the Number of Sections That Contained SI

<table>
<thead>
<tr>
<th>Course Type</th>
<th>Fall 2012</th>
<th>Spring 2013</th>
<th>Fall 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of Sections</td>
<td>Number of Sections with SI</td>
<td>Number of Sections</td>
</tr>
<tr>
<td>Precalculus</td>
<td>4</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Calculus I</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Calculus II</td>
<td>5</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Calculus III</td>
<td>2</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Applied Mathematics I</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Applied Mathematics II</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>General Chemistry I</td>
<td>5</td>
<td>1*</td>
<td>0</td>
</tr>
<tr>
<td>General Chemistry II</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Physics with Calculus I</td>
<td>4</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Physics with Calculus II</td>
<td>1</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Statics</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Mechanics of Materials</td>
<td>2</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Structural Analysis</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Fluid Mechanics</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Circuits I</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Circuits II</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Computer Apps for EE</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Signals and Systems</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Impact of Supplement Instruction at The Citadel

The total impact of SI has become clearly evident each semester it is offered. As SI is placed into additional courses, SI leaders continue to promote the sessions, and students attending the sessions realize positive results, attendance should continue to rise. Figure 5 shows the increase in student attendance each semester that SI is offered in those courses. Fall 2013 was by far our highest attendance totals for SI sessions, with 230 visits in Chemistry courses, 548 visits in Engineering courses, 479 visits in Mathematics courses and 62 visits in Physics courses.
During the Fall 2013 semester midterm grades were collected from the courses that contained an SI Leader. At the end of the semester midterm grades were compared to final grades for those students attending SI sessions verse the students not attending SI Sessions. Table 2 displays the grade point differential between midterm grades and final grades.

Table 2 – Fall 2013 Summary of Grade Point Differential Between SI attendees and Non-SI attendees

<table>
<thead>
<tr>
<th>Course</th>
<th>SI Attendees</th>
<th>Non-SI Attendees</th>
<th>Delta</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math 119: Pre-calculus</td>
<td>3 pts</td>
<td>0 pts</td>
<td>3 pts</td>
</tr>
<tr>
<td>Math 131: Calculus I</td>
<td>3 pts</td>
<td>1 pt</td>
<td>2 pts</td>
</tr>
<tr>
<td>Math 132: Calculus II</td>
<td>- 3 pts</td>
<td>- 3 pts</td>
<td>0 pts</td>
</tr>
<tr>
<td>Math 231: Calculus III</td>
<td>2 pts</td>
<td>- 1 pt</td>
<td>3 pts</td>
</tr>
<tr>
<td>Math 335: Applied Engineering Math II</td>
<td>3 pts</td>
<td>4 pts</td>
<td>- 1 pt</td>
</tr>
<tr>
<td>Chemistry 151: General Chemistry I</td>
<td>8 pts</td>
<td>5 pts</td>
<td>3 pts</td>
</tr>
<tr>
<td>Electrical 201: Elec Circuit Analysis I</td>
<td>1 pt</td>
<td>1 pts</td>
<td>0 pts</td>
</tr>
<tr>
<td>Electrical 309: Signals and Systems</td>
<td>3 pts</td>
<td>0 pts</td>
<td>3 pts</td>
</tr>
<tr>
<td>Civil 304: Mechanics of Materials</td>
<td>- 3 pts</td>
<td>3 pts</td>
<td>- 6 pts</td>
</tr>
<tr>
<td>Civil 205: Surveying</td>
<td>8 pts</td>
<td>3 pts</td>
<td>5 pts</td>
</tr>
<tr>
<td>Physics 222: Physics with Calculus II</td>
<td>- 3 pts</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

From the above data it can be shown that overall SI sessions help students achieve better grades. With the exception of Civil 304: Mechanics of Materials and MATH 335: Applied Engineering Math II, these courses show a statistical anomaly and could be possibly discarded from the data collected. However, the effectiveness of the SI Leader is being investigated.
As shown in Figure 6, the SI program has helped increase retention in the School of Engineering by approximately ten percent from fall to spring since the 2010 and 2011 academic years. This data was collected by studying enrollment numbers in Introduction to Civil Engineering (CIVL 103), Engineering Drawing (CIVL 101), Surveying (CIVL 205), Introduction to Electrical Engineering (ELEC 106), Computer Applications for Electrical Engineers (ELEC 206), and Circuits I (ELEC 202). Because these courses are taken in sequence by all engineering majors, they provide a strong indicator of accurate enrollment numbers and retention. In addition, the data indicates that overall retention from freshmen to sophomore year increased by seven percent between the 2010 and 2011 academic years and the 2012 academic year. The School of Engineering is optimistic that this increase will continue into the 2014 academic year. Because most of the attrition in the School of Engineering at The Citadel occurs during the freshmen year and between the freshmen and sophomore year, the SI program made a tremendous contribution toward increasing enrollment by 10% in STEM majors by 2015.

![Figure 6: Retention of Engineering Freshmen Students.](image)

Full-time enrollment in both CEE and ECE has seen a steady increase as well since introducing SI to students. Figure 7 shows the full-time enrollment by major and since 2010 where there has been a 10% increase in enrollment for both majors and the current total for 2013 is 370 cadet students (The Citadel has a full-time evening engineering undergraduate program as well). Final totals for 2013 are projected to be at 450 students with a trend that increases roughly 50 students per academic year going forward. SI will not be the only initiative used to continue increasing retention, but it will continue to be at the forefront of efforts by the faculty and staff at The Citadel.
Clearly, the introduction of the freshmen SI program in the fall of 2012 increased retention in the School of Engineering at The Citadel; however, this data does not reflect the complete impact of the program. The attitudes of freshmen and sophomore students and the atmosphere of the engineering buildings at night has transformed. Before the introduction of the program, during ESP only junior and senior engineering cadets could be found in the engineering buildings. Often, these students were in computer labs working on lab reports, design projects, and other homework assignments. Now, freshmen, sophomore, junior, and senior cadets can be found in all rooms of the building. Throughout the duration of ESP, upperclassmen lead SI sessions for freshmen and sophomore students. Interaction occurs among all students in each department. Students are focused, driven, and mastering content collaboratively in a way that previously did not exist. The change in the culture and attitudes of students in the School of Engineering has been the most positive impact of all.

**Supplement Instruction at The Citadel Moving Forward**

Faculty surveys were conducted at the end of the fall 2013 semester for faculty teaching courses in engineering, math, chemistry and physics that had an SI leader assigned to their course. Survey results showed that a majority of the faculty saw SI to be beneficial to the course they
were teaching. However, a needed area of improvement was SI promotion during class as it was not continually happening at each class session. This posed question on how effective the SI leaders were at actually promoting SI and whether the shift should change to faculty promoting the SI session. Research at other institutions should be conducted to conclude which method would be most effective for promotion of an SI program. At some institutions faculty offer extra credit in the course and this could be explored as an option at The Citadel.

As shown in Table 3, SI leaders were not always attending the class on a regular basis and this could possibly improve attendance for the SI session if the presence of an SI leader was more prominent throughout the semester. It becomes critical for the SI leader to be present and assure the students that they are following the course material that is being covered by the professor and can assess what difficulties the students may be facing. One faculty member noted that the SI program helped bridge the gap between the material that the students do not learn the first time they see it in class and it sinks in the second time around.

Table 3– Faculty Survey Results Conducted at the End of the Fall 2013 Semester.

<table>
<thead>
<tr>
<th>Questions</th>
<th>Not Sure</th>
<th>Never</th>
<th>Sometimes</th>
<th>Usually</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td>The SI Leader sufficiently made contact with you</td>
<td>0%</td>
<td>13%</td>
<td>27%</td>
<td>13%</td>
<td>47%</td>
</tr>
<tr>
<td>The SI Leader attended class regularly if schedule permitted</td>
<td>0%</td>
<td>7%</td>
<td>20%</td>
<td>27%</td>
<td>47%</td>
</tr>
<tr>
<td>The SI Leader promoted SI during class</td>
<td>0%</td>
<td>20%</td>
<td>33%</td>
<td>27%</td>
<td>13%</td>
</tr>
<tr>
<td>The SI Leader modeled behaviors of a good student</td>
<td>7%</td>
<td>0%</td>
<td>27%</td>
<td>20%</td>
<td>47%</td>
</tr>
<tr>
<td>The SI Leader went beyond the call of duty by providing extra time or additional SI sessions</td>
<td>47%</td>
<td>13%</td>
<td>27%</td>
<td>0%</td>
<td>7%</td>
</tr>
<tr>
<td>As an instructor and based on what you've heard from students, do you think SI sessions for your course are helpful</td>
<td>13%</td>
<td>7%</td>
<td>13%</td>
<td>40%</td>
<td>27%</td>
</tr>
</tbody>
</table>

Conclusion

Based on the data collected and analyzed in this paper it was concluded that the SI program has become extremely important to the success of engineering students at The Citadel. The DFW rates are decreasing and final grades earned are increasing from C’s to B’s or D’s to C’s and allowing students to continue in their chosen engineering major.
Having the SI Leader attend class assures the students that sessions are closely following course material with key instructor focal points at the center. Sessions where the grade point does not increase could point to lack of SI Leader class attendance, session promotion, attendance of Friday lunch training sessions, and/or effectiveness. Each of these indicators are being currently assessed.

Another area for improvement would be the DFW rate in engineering specific classes. For Civil & Environmental Engineering courses the overall DFW rate was 9.2% in fall 2012 and increased to 13% in fall 2013. Electrical and Computer Engineering overall DFW rate was 14% in fall 2012 and 17.7% in fall 2013. These DFW rates point to courses specific to engineering that could benefit from the addition of an SI Leader in the course.

In addition, the SI program continues to grow across the entire Citadel campus. During the spring 2014, SI is currently being offered in 38 course sections in ten different disciplines. Data collection has continued in the spring 2014 semester with Midterm grades and also a new Midterm Evaluation Survey as a checkpoint to understand students’ perception of the SI program and to ensure that it is being advertised appropriately in assigned courses.

SI does require administrative and financial resources; however, the retention and student success in engineering, with a shortage of engineering graduates within the US, are clearly possible.

References


